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SOIL SCIENCE

September 1989
Vol. 148, No. 3
Printed in U.S.A.

DOWNSLOPE MOVEMENT OF CHLORSULFURON AFTER CONVENTIONAL AND OVER-SNOW APPLICATIONS TO WINTER WHEAT[1]

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Chlorsulfuron was applied conventionally in the fall and over snow-covered winter wheat in an aqueous suspension with graphite powder and urea ammonium nitrate in February and March to determine downslope herbicide movement in runoff. Plots were established in fields with slopes of 8 to 14%. Snow depth during winter application ranged from 20 to 60 cm. Soil samples collected in the spring 0.6, 0.9, 1.5, 2.4, 3.7, 5.2, 7, and 9.1 m downslope from each treated plot were analyzed using a lentil bioassay technique to determine the presence of herbicide. Chlorsulfuron residues were detected as far as 3.7 m downslope from plots. Less downslope herbicide movement occurred when chlorsulfuron was applied with graphite over snow than when applied as a conventional fall treatment. If herbicide is applied over snow without graphite, significant amounts may be lost as a result of erosion.

Application of chlorsulfuron [2-chloro-N-(((4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino)carbonyl)benzenesulfon-amide] or other sulfonylurea herbicides to snow-covered winter wheat has effectively controlled weeds (Gavlak et al. 1988; Tindall and Dewey 1987). Applying herbicides with graphite and urea ammonium nitrate (UAN) fertilizer could significantly reduce costs in winter-wheat-producing areas where surface-darkening agents are routinely applied to control snow mold and other diseases (Cartee et al. 1987; Tindall 1986). Applying herbicide over snow is prohibited on all sulfonylurea product labels, however, due to possible herbicide movement in surface runoff. We have not seen any evidence of significant herbicide movement due to surface runoff in any of our studies of the efficacy of over-snow herbicide applications. However, we did not measure for trace levels of herbicide outside treated plots. This research determined the potential for downslope movement of the herbicide (chlorsulfuron) at various slopes and snow depths.

MATERIALS AND METHODS

Field plots were established on dryland locations at Cache Junction, Utah, and Soda Springs, Idaho, in the winter of 1987–88. Fields had been planted to winter wheat (*Triticum aestivum* L., cv. Manning). Grain rows were perpendicular to the slope at Cache Junction, but parallel to slope at Soda Springs. All plots were oriented perpendicular to the slope and arranged in a randomized complete block design with treatments replicated three times at each location.

Individual plots consisted of a 7.6- by 11.-1 m soil sampling area immediately downslope from a 7.6- by 4.1-m herbicide-treated "source" area. Snow in sampling areas was sprayed with an aqueous suspension of UAN and powdered graphite (50-μ particle size) to enhance snow melt and facilitate water runoff from herbicide-treated plots. Plots were separated by 3-m, unsprayed snow strips parallel to the slope, which prevented lateral surface water movement from one treated plot to another as snow melted in the spring.

Cache Junction plots were established on a north aspect with 8% average slope. Soil was a Collinston series fine-silty Typic Calcixeroll silt loam with 24 to 25% clay. Treatments consisted of 0.054 kg ai/ha chlorsulfuron applied in an aqueous suspension: (1) alone, as a conventional fall treatment; (2) with 28 kg/ha N (as UAN) in an over-snow treatment; and (3) with 28 kg/ha UAN plus 20 kg/ha graphite as another over-snow treatment. Fall treatments were applied 5 November 1987, and over-snow treatments were applied 9 February 1988. Snow depth at the study site on 9 February was 20 cm. On 27 February, the graphite-treated plots were bare, while snow depth in untreated plots averaged 18 cm.

Plots at Soda Springs were located on a southeast aspect with a 14% average slope. Soil was

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Received 30 Jan. 1989; revised 25 May 1989.

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an RIN series coarse-silty Pachic Cryoboroll sandy loam to silty loam with 20 to 21% clay. Two treatments (0.054 kg ai/ha chlorsulfuron and 28 kg N/ha as UAN, with and without 20 kg/ha graphite), were applied 4 March 1988, when the average snow depth was 60 cm. A conventional fall treatment was not included in the Soda Springs study.

Treatments at both locations were applied with a CO_2 backpack sprayer delivering 166 L/ha at 207-kPa pressure. Over-snow applications were made by workers on cross-country skis to minimize snow disturbance.

Soil samples were collected 18 March 1988 from the Cache Junction location and 5 May 1988 from Soda Springs for bioassay analysis. All snow had melted prior to sampling dates. Samples were collected from the top 5 cm of soil, 0.6, 0.91, 1.5, 2.4, 3.7, 5.2, 7, and 9.1 m downslope from the edge of the treated portion of each plot. Samples were also collected from inside treated areas plots and from three untreated areas above the plots. Soil sampling equipment was thoroughly washed between each use with a 10% solution of Chlorox in water to prevent cross-contamination.

In the greenhouse 0.5 kg of soil from each sample was placed in 1/2-L pots, and each pot planted with seven uniform fungicide-treated lentil seeds. Ten days later, plants in each pot were thinned to four uniform seedlings. Pots were irrigated with a limited but equal amount of water to minimize drainage and prevent possible leaching of herbicide. Forty days after planting, lentils were cut at the soil surface, oven-dried at 70°C for 24 h, and weighed. Limits of detectable chlorsulfuron residue were determined statistically using Dunnett's Comparison Test ($d_{.05}$) against the untreated control group (Montgomery 1984). Lentil dry weights corresponding to a given sampling distance were compared statistically using a conventional $LSD_{(.05)}$.

Weed control efficacy (%) was determined by visual evaluation using a 0 to 100 rating scale on 5 May at Soda Springs, and on 10 May 1988 at Cache Junction.

RESULTS AND DISCUSSION

Distance of downslope herbicide runoff at Cache Junction is represented in Fig. 1. Chlorsulfuron residues were detected downslope from all treated plots, an indication of lateral herbicide movement in runoff. No chlorsulfuron residue after any winter or fall applications was detected at or beyond a distance of 2.4 m. There were detectable residues 1.5 m from plots receiving either winter (without graphite) or fall (conventional) treatments. Chlorsulfuron from graphite-treated plots was detected 0.9 m downslope. There was a significant ($P = .05$) difference in lentil dry weight between the winter chlorsulfuron + graphite application and the other two treatments 1.5 m from the plot, indicating that chlorsulfuron applied in a conventional manner in the fall moved farther downslope at Cache Junction than when applied over snow with graphite. There was no measurable difference in downslope movement between the conventional application in the fall and the winter application without graphite.

A bioassay of soil samples from the Soda Springs plots also indicated that chlorsulfuron

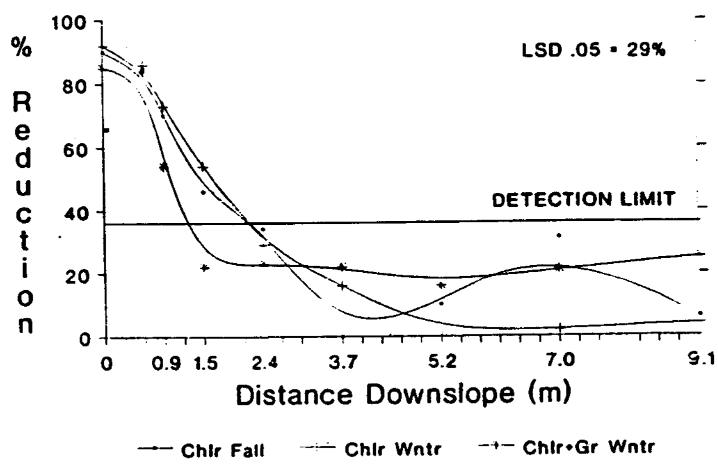

FIG. 1. Percentage of reduction in dry weight of lentils grown in soil samples collected downslope from plots treated with chlorsulfuron, applied conventionally and over snow, at Cache Junction.

TABLE 1

Dry weight of lentils grown in soils collected downslope from plots treated with chlorsulfuron, over snow, at Soda Springs

Treatment and timing	Rate, kg ai/ha	Distance downslope, m	Lentil dry wt, mg
Chlorsulfuron	0.054	0.00	87
+ UAN	28.0	0.61	127
(winter)		0.91	187
		1.52	227
		2.44	302
		3.66	343
		5.18	383
		7.00	410
		9.10	475
Chlorsulfuron	0.054	0.00	16
+ UAN	28.0	0.61	73
+ graphite	20.0	0.91	129
(winter)		1.52	187
		2.44	195
		3.66	273
		5.18	375
		7.00	471
		9.10	485
Control		-	486
$d_{(.05)}$			164
Detection limit			322
$LSD_{(.05)}$			118

can move downslope when applied over snow with or without graphite (Table 1). After herbicide application with graphite, residual chlorsulfuron was detected up to 3.7 m downhill. The greater movement noted at Soda Springs may have been related to steepness of slope, snow depth, or both, as both were considerably greater at this location.

Addition of graphite at Soda Springs did not appear to reduce downslope movement of herbicide as it did at Cache Junction. On the contrary, chlorsulfuron residues at Soda Springs were detected farther downslope when graphite was included than when herbicide was applied alone (3.7 versus 2.4 m). The cause of this apparent contradiction between herbicide runoff behavior at the two locations is believed to be related to wind erosion of herbicide in surface snow and a resultant reduction in the amount of herbicide available to move downslope as snow eventually melted. On 18 and 30 March at Soda Springs, we observed extensive drifting of surface snow away from plots not treated with graphite, but drifting did not seem to occur in graphite-treated plots. Plots treated with graphite appeared less vulnerable to wind erosion because of rapid initial melting of surface snow on the day of application (up to 5 cm), followed by freezing at night, which formed a hard wind-resistant crust. This freeze-thaw cycle was repeated each day and night until all the snow had completely melted. However, snow on the surface of plots not treated with graphite was much slower to melt, remaining powdery and subject to wind erosion for days after the initial herbicide application. The difference in time required for snow to melt is demonstrated by the fact that average snow depth at Soda Springs 26 d after application was 6 cm in graphite plots, but still 50 cm in nongraphite plots.

Weed-control data from the Soda Springs location also seem to support the argument that much of the herbicide in surface snow on nongraphite plots was lost due to wind erosion. Though the same rate of chlorsulfuron was applied to all treated plots, weed control in nongraphite plots was near zero, but averaged 87% in plots treated with graphite (Table 2). This suggests that little herbicide applied without

TABLE 2

Average percentages of broadleaf weed control resulting from fall conventional and winter over-snow application of chlorsulfuron at Cache Junction and Soda Springs

Treatment and timing	Rate,	Location	
		Cache Junction[a]	Soda Springs[b]
	kg ai/ha	%	
Chlorsulfuron + UAN (fall)	0.054 28.0	100	-
Chlorsulfuron + UAN (winter)	0.054 28.0	100	3.3
Chlorsulfuron + UAN + graphite (winter)	0.054 28.0 20.0	100	86.7
$LSD_{(.05)}$		-	10.4

[a] Treatments applied 5 Nov. 1987 (fall) and 9 Feb. 1988 (winter). Weed control determined by visual rating 10 May 1988. Weed species evaluated was prickly lettuce (*Lactuca serriola* L.).

[b] Treatments applied 4 March 1988 (winter). Weed control determined by visual rating 5 May 1988. Weed species evaluated was field pennycress (*Thlaspi arvense* L.)

graphite actually reached the soil surface within the plots, while normal amounts of chlorsulfuron reached the plot soil surface when applied with graphite. The lost herbicide can't be accounted for by the runoff data, giving more reason to suspect that it was widely dispersed and diluted by wind erosion before snow melted. No wind erosion of snow was observed in any plots at Cache Junction, and weed control was 100% in both graphite and nongraphite treatments.

CONCLUSIONS

When chlorsulfuron was applied conventionally in the fall, herbicide residues were detected farther downslope than when applied over snow with graphite and UAN.

Wind erosion appeared to remove significant amounts of herbicide in drifting snow from nongraphite plots at the Soda Springs site. Wind erosion is common in many dryland winter-wheat-producing areas and could easily disperse herbicides applied over snow without graphite.

We believe that applying chlorsulfuron on snow will not significantly increase the threat of downslope herbicide movement in runoff from melting snow; however, application in this manner will not be practical unless the apparent wind erosion problem is solved. Graphite appeared to substantially reduce losses from wind erosion, but may not completely eliminate herbicide drifting.

ACKNOWLEDGMENTS

We appreciate the partial support of this research by Superior Graphite Co., Utah Agricultural Experiment Station, and USDA Extension Service.

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JOURNAL OF FERTILIZER ISSUES Volume 3, Number 4, October - December, 1986, Pages 129-132

Darkening Agents in a UAN Solution: Influence on Snow Mold and Yield of Winter Wheat

T. A. Tindall[1]

ABSTRACT

Snow accumulations of up to 2 and 3 ft are not uncommon in areas where winter wheat is grown in the Intermountain West. If snow accumulates before the soil has frozen, snow mold becomes an increasingly serious problem. Snow mold usually consists of two genera of fungi, *Typhula incarnata* Lasch ex Fr. (Speckled snow mold) and *Fusarium nivale* Fr. Cesati (Pink snow mold). To limit damage to winter wheat grown in the Pacific Northwest, techniques were developed to melt snow early, thus exposing the soil and wheat to the atmosphere and creating conditions less favorable to snow mold. Farmers originally used flyash (the by-product from coal-fired power plants), which is satisfactory. However, because most wheat growers topdress N in the spring, it became desirable to apply nitrogen with the darkening agent to save a trip across their fields. The pH of flyash is often near 12, high enough to volatilize NH_4^+ in urea ammonium nitrate (UAN) solution. Therefore, several other darkening agents compatible with UAN were evaluated as suitable darkening agents to melt snow and reduce the incidence of snow mold on winter wheat.

Field studies were conducted in 1985-86 using UAN as carrier solution containing various grades of graphite, coal and coke to increase the rate of snow melt. These darkening agents were applied to approximately 2 ft of snow in 1985 and 15 inches in 1986, covering dryland winter wheat affected by snow mold. The treatments were applied at 18 lb/ac in a 28% nitrogen UAN solution. The material was applied in 1985 with a snowmobile equipped with 50-ft spray booms.

There were differences between darkening materials and the UAN-graphite mixture in snowmelt, reflectant energy and surface temperature. Overall rate of snowmelt, radiant energy, soil nitrogen levels, soil moisture levels, snow mold parameters and grain yields were determined. There were significant differences among treatments in rate of snowmelt, number of diseased plants and yield. Decreasing trends in soil moisture indicate that the UAN-graphite treatment might enable tillage earlier in the spring. The improved yield indicates the usefulness and potential of graphite-nitrogen mixtures in agriculture, turf, forest and range land management. This paper is presented as a methodology for darkening agents applied to snow using UAN as a carrier solution.

Additional index words: **snowmold, graphite, flyash, UAN, snowcover, winter nitrogen application.**

F[illegible] crops in the Pacific Northwest suffer from a disease associated with snowmold fungi (7). Losse's from snow mold vary markedly from year to year, but the disease seriously affects wheat yields in the Pacific Northwest 70% of the time (8, 9). The greatest losses recorded have been in Douglas County, Washington, where 169,000 ac were destroyed in 1968, and estimated losses exceeded $2,000,000. In 1984, 33,000 ac of dryland winter wheat were seriously affected in Power County in southern Idaho.

Universities in the Northwest have been involved with the control of snow mold for several years (2, 4). Researchers have found application of dark material such as flyash to the snow surface will hasten snowmelt and limit severity of the disease (5, 7). Conditions favorable to the development of snow mold result when an early snow cover has persisted well into the spring, particularly if the soil is not frozen. Removing snow earlier in spring allows the soil to freeze, thus creating conditions less favorable to snow mold and more conducive to wheat development (3). Nielson and Cartee have reported an average yield increase of 50% using flyash since 1974 (6).

Flyash, generally applied at the rate of 200 lb/ac, will increase snowmelt but its high pH (10-12) also increases ammonia volatility when UAN is mixed with flyash. Flyash is also generally unsuitable because of its indiscriminate particle size, which includes particles (without further screening) large enough to plug spray nozzles. The sample we evaluated had 46% that would not pass through a 28 mesh screen. Nitrogen loss as NH_3 volitilization was measured and as much as 50% can be lost using flyash as compared to no significant loss (0.05%) utilizing graphite with UAN. Therefore, graphite, coal or coke were evaluated as possible alternatives to flyash in established field trials.

This paper presents general application guidelines for UAN and darkening agent mixtures. The technique of using darkening agents with N solutions may also decrease overall soil erosion by limiting snowmelt and therefore runoff to only daylight hours (5). With graphite treatment, snowmelt is often more gradual than normal melting of spring snowpack. This occurs because the dark particle intercepts the radiant energy of the sun, increases the particle temperature and radiates this energy to the adjacent snow crystal and melting occurs. This in turn causes a more gradual snowmelt in comparison to melt through elevated air temperatures alone.

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The smowmold control method proposed here involves application of graphite suspended in urea ammonium nitrate solution. This suspension is applied to the snow surface with a liquid fertilizer applicator attached to a snowmobile.

MATERIALS AND METHODS

Field experiments conducted in late winter through early spring of 1985-86 were located four miles north of the Blue Creek Experiment Station on the Utah-Idaho border. The plots were established on the Parleys silt loam (fine-silty, mixed mesic, Calcic Argixeroll). Average annual precipitation after treatment applications was three inches (1985), of which 1/3 occurred as snow.

This soil is representative of those in this wheat-producing region and has a pH of 7.6. The soil is well drained on a 3% slope. Nitrogen in 1985, as anhydrous ammonia, was applied preplant at 60 lb/ac, enough to satisfy the N requirements of the wheat under these dryland conditions. Soil testing did not indicate the need for additional fertilizer nutrients.

The experimental design in 1985 was a randomized complete block. The plots measured 50 x 500 ft. The large plot size was necessary to accommodate commercial application equipment.

Winter wheat (*Triticum aestivium* L., cv. Manning) was planted on September 15, 1984, and treatments were applied in late February 1985. Snow depth at the time of treatment was 27 inches. Treatments were applied with a converted snowmobile equipped with a 500-gal stainless-steel holding tank and sprayers mounted on two sidebooms capable of spraying a 50 ft swath. The various treatments are listed in Table 1.

The graphite and coal treatments were applied at 18 lb/ac as a solution of UAN containing a 2% concentration of bentonite clay to help prevent separation of the darkening agent. The nitrogen concentration of UAN (32% N) was diluted to 28% N to prevent salting out at near 0° F temperatures. There were few problems at these lower concentrations with freezing in the lines or spray nozzles. This was seen as another advantage of using UAN as a carrier solution.

Parameters evaluated during the 1985 growing season included: (a) snowdepth, (b) net radiation, (c) temperature, (d) soil moisture, (e) soil NO_3^--N, (f) snow mold damage to wheat plants, (g) necrosis of wheat plants resulting from snow mold, (h) grain protein, and (i) grain yield. Snowdepth measurements were made two weeks after treatment application and at three-day intervals until May 10. At this time all of the snow had melted from the plot areas. Net radiation determined how much of the sun's radiant energy was being absorbed by the particles and how much was reflected. The snowmelt increases as the snow's albedo (total reflectant energy of the snow surface) decreases. Reflectance was measured with a new radiometer. Surface temperatures were measured with an infrared thermometer. Soil moisture and NO_3^--N were measured on 0-12 inch soil samples collected after snowmelt was completed from off the entire plot area. All plots were evaluated both for snow mold damage to wheat plants and wheat necrosis caused by snow mold by randomly selecting a square meter area and evaluating the plants for disease. The process was repeated several times within a treated area to obtain a representative sample. Snowmold damage including necrosis of the plants was evaluated under the direction of a plant pathologist who clearly identified the cause of wheat damage, including necrosis from the snow mold organism (10). A predetermined index scale ranged from 1 (no effect) to 10 (complete necrosis). Plots were harvested on August 15, 1985.

Data were analyzed by analysis of variance. Where significant differences existed, treatment means were separated with least significant differences.

Table 1. Darkening materials utilized for snowmelt.

Material	Treatment	Particle size	pH†	Rate of application
				lb/ac
Fly ash	A	46% passing 28 mesh screen	11.9	200
Ground coal	B	80 microns	7.6	18
Graphite 3739	C	5 microns	7.4	18
Graphite 3226	D	50 microns	7.4	18
Coke (99% carbon)	E	60 microns	7.4	18
Graphite 3124	F	60 microns	7.4	18
Graphite 8600	G	65 microns	7.4	18
Coal - 25% graphite	H	70 microns	7.5	18
Control	I			

† pH of UAN alone was 7.4.

The 1986 field plots were established to look at nitrogen movement through snow into the soil. UAN alone and in combination with graphite and flyash were applied to the snow surface. There was no significant difference at the 0.05 level to snowmelt comparing UAN and the true control. The following results refer to the 1985 initial study. The N discussion, including efficiency and movement will follow in a subsequent paper.

RESULTS AND DISCUSSION

The effects of treatments on snowmelt over time and comparison of rate of snowmelt among those treatments of greatest difference are illustrated in Table 2. Snowmelt rates were higher in plots treated with graphite 3739 or 3124 than in plots treated with flyash, coke, coal and the control (LSD 0.05 = 1.2). Treatment C, graphite material 3739 (5 microns), quickly went into suspension with nominal mixing and consistently provided the most rapid snowmelt. The flyash treatment (A), which had often been used to accelerate snowmelt in the past, was one of the least effective materials in accelerating snowmelt.

Soil moisture was measured when all of the snow had melted from the plot area. A significant difference at 0.05% confidence level was seen when comparing graphite 3739 with the control. There was 18% less water by weight in this graphite treatment than the control. There was no significant difference in the other treatments. Further work is expected to be done in this area in an attempt to relate snow removal to field accessibility earlier in the spring.

Table 3 shows a significant ($p < 0.05$) reduction in the percentage of damaged or dead wheat plants caused by snow mold. The treatment least affected by snow mold was graphite treatment 3739, while the plot most affected by snow mold was the check plot, which also had the longest standing snow cover.

Table 3. Percentage of snowmold affected wheat.

Treatment	% damaged	% killed
Fly ash	26.0b*	10.9b
Ground coal	27.0c	15.9c
Graphite 3739	22.5a	5.8a
Graphite 3226	24.0b	12.2b
Coke	24.5b	17.9c
Graphite 3124	22.5a	7.0a
Graphite 8600	24.5b	12.0b
Coal - 25% graphite	25.5bc	10.5b
Control	30.0d	18.0c

* Means followed by the same letter are not significantly different at the 0.05 confidence level.

Table 4 shows that graphite treatment significantly (LSD 0.05 = 3.82) increased yields, compared to the control plot, flyash, coke, coal and other graphite treatments. Graphite 3226 increased yields by as much as 22% (49 bu/ac compared to about 37.5 bu/ac for the control area). These yields are related to snow mold disease rather than soil moisture relations. There was no correlation between the darkening agents' effect on soil moisture and the subsequent yields.

Table 4. Yield of winter wheat as related to snowmelt and snowmold.

Treatments	Yield
	bu/ac
Fly ash	44.5bc*
Coal	42.0bcd
Graphite 3739	45.5ab
Graphite 3226	49.0a
Coke	45.0b
Graphite 3124	38.5de
Graphite 8600	38.0e
Coal - 25% graphite	43.0bc
Control	37.5e

* Means followed by the same letter are not significantly different at the 0.05 confidence level.

Table 2. Rate of snowmelt associated with darkening materials in UAN solutions.

	Snow depth (inches)						
Material	Date: 3/19	3/21	3/26	3/31	4/2	4/5	4/10
Fly ash	20b*	17.5d	13.5c	10d	6cd	0a	0
Ground coal	19b	17.5d	13.5c	10d	5c	0a	0
Graphite 3739	16a	12a	4a	0.5a	0a	0a	0
Graphite 3226	17a	13ab	5a	1d	0a	0a	0
Coke (998 carbon)	23c	18de	14d	12e	7d	0.5a	0
Graphite 3124	17a	14bd	10b	5b	1a	0a	0
Graphite 8600	17a	12.5a	9b	7c	3b	0.5a	0
Coal - 25% graphite	19b	15c	9b	7c	5b	1	0
Control	24c	19c	17c	14.5e	12e	5c	0

* Treatment means followed by the same letter are not significantly different at the 0.05 confidence level.

CONCLUSIONS

Application of darkening agents in a nitrogen solution in late winter or early spring can significantly decrease snow pack, increase winter wheat yields, decrease number of diseased plants and decrease plant necrosis caused by snow mold. This study also indicates that applying graphite-nitrogen solutions may help decrease soil moisture levels, thus enabling spring field work to begin sooner. Future evaluations need to be made under a variety of nitrogen rates, slopes, soil conditions, climatological parameters as well as other field conditions.

Additional information is needed on application of graphite-nitrogen solutions in combination with herbicides and fungicides. Preliminary investigations have been initiated to evaluate some of these critical areas of concern. Nitrogen relations will be further evaluated on field studies already initiated. Separations will be made to determine if the entire crop demand for nitrogen can be made following this methodology.

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Applying Herbicides Over Snow to Control Weeds in Winter Wheat (*Triticum aestivum*)[1]

STEVEN A. DEWEY, JAFAR ASGHARI, and TERRY A. TINDALL[2]

Abstract. Chlorsulfuron at 0.018 kg ai/ha, metsulfuron at 0.0045 kg ai/ha, and 2,4-D at 1.1 kg ae/ha plus dicamba at 0.28 kg ae/ha were applied over snow-covered winter wheat to study the feasibility of combining herbicides with a graphite snow-removal treatment. Chlorsulfuron or metsulfuron applied on snow effectively controlled annual broadleaf weeds when tank mixed with urea ammonium nitrate (UAN) at 28 kg N/ha and graphite powder at 20 kg/ha. Over-snow treatments of 2,4-D plus dicamba plus UAN did not control weeds. There was no antagonism or synergism among herbicides, UAN, or graphite. **Nomenclature:** Chlorsulfuron, 2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) amino]carbonyl]benzenesulfonamide; dicamba, 3,6-dichloro-2-methoxybenzoic acid; metsulfuron, 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]-carbonyl]amino]sulfonyl]benzoic acid; 2,4-D, (2,4-dichlorophenoxy)acetic acid; UAN, urea ammonium nitrate; winter wheat, *Triticum aestivum* L. cv Manning.

Additional index words: Darkening agent, graphite, snow mold, UAN, chlorsulfuron, dicamba, metsulfuron, 2,4-D, *Veronica campylopoda*, CHEAL, LACSE, THLAR, CLCPA.

INTRODUCTION

Snow mold is a serious disease in many winter wheat-producing areas of the United States. Annual losses are estimated at millions of dollars in northern Utah and southern Idaho (5). More than 13 350 ha of dryland winter wheat in Power County, ID (7), and over 68 390 ha in Douglas County, WA (6), were destroyed by snow mold in a single season. The two fungi responsible for causing damage, gray snow mold *Typhula incarnata* Lasch ex Fr.), and pink snow mold [*Fusarium nivale* (Fr.)Ces.], occur most often when snow falls on unfrozen soil early in the fall and persists into spring (2, 5); the insulating effect of snow prevents soil from freezing over the winter. Removing snow cover in late winter or early spring allows the soil surface to freeze, thus preventing further development of snow mold organisms (1, 4, 6).

Early snow removal from winter wheat fields in the Intermountain West is routinely achieved by applying surface darkening agents such as fly ash or graphite over snow-covered fields (3, 4, 5, 7). In 11 yr of research in northern Utah, darkening agents caused snow to melt an average of 20 days earlier and increased average wheat yield by 50 to 70% (3). Combining nitrogen fertilizer solution, herbicide, and graphite could reduce production costs, top dress winter grain with nitrogen fertilizer, control weeds, and accelerate snow removal in one operation.

This research was designed to determine 1) if herbicides applied over the snow to winter small grains would consistently control weeds, 2) how herbicide efficacy of over-snow applications compares with conventional fall applications, and 3) if graphite and UAN fertilizer solutions are antagonistic or synergistic when tank mixed with herbicides.

MATERIALS AND METHODS

Experiments were conducted in 1987 and 1988 on dryland winter wheat at four locations in Utah and Idaho. Individual 4.1- by 7.9-m plots were arranged in a randomized complete block design with treatments replicated four times at each experiment location. Herbicides were applied in an aqueous solution of UAN using a CO_2-pressurized backpack sprayer delivering 170 L/ha at 210 kPa pressure. UAN concentration was equivalent to 28 kg N/170 L. Graphite powder (50 micron particle size) was applied at 20 kg/ha as a tank mix with herbicides and UAN.

Chlorsulfuron at 0.018 kg/ha, metsulfuron at 0.0045 kg/ha, and 2,4-D plus dicamba at 1.1 plus 0.28 kg/ha were applied on snow at Location A (China Hat, ID) and at Location B (Conda, ID) (Table 1). A 2-ethylhexyl ester formulation of 2,4-D was applied at Location A and an alkanolamine salt at Location B. Two additional experiments were initiated in the fall of 1987

[1]Received for publication Jan. 26, 1989, and in revised form July 10, 1989. Utah State Univ. Agric. Exp. Stn. Paper No. 3760.

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Table 1. Calendar of events and selected site conditions at experiment locations.

Parameter	Location: China Hat (A)	Conda (B)	Cache (C)	Pocatello (D)
Application date:	(1987)	(1987)	(1988)	(1988)
Fall (1987)	...	...	Oct. 29	Nov. 5
Winter	Feb. 27	March 6	Feb. 9	Feb. 9
Snow depth[a] (cm)	51	18	20	32.5
Average slope (%)	4	3	8	2
Evaluation date	June 12	June 12	May 10	May 4

[a]Average snow depth at time of winter herbicide application.

at Locations C (Cache Junction, UT) and D (Pocatello Valley, ID), expanded to include both conventional fall applications and winter over-snow herbicide treatments. Chlorsulfuron and metsulfuron were applied at 0.018 and 0.0045 kg/ha respectively (Table 1). Dicamba and 2,4-D were not included in experiments at Locations C and D.

Snow depth in nontreated check plots was measured at the time of winter herbicide application at each location (Table 1). Nine days after treatment, snow depth was measured in each plot at Location A to evaluate effects of herbicide on snow-melting capacity of graphite treatments. Snow depth differences after winter treatments at Locations B, C, and D were evaluated visually but were not measured.

Soils at Locations A and B were a Rin series coarse-silty Pachic Chryoboroll sandy loam to silty loam. Soil at Location C was a Collinston series fine-silty Typic Calcizeroll silt loam. Soil at Location D was Parleys series fine-silty mixed mesic Typic Agrixeroll silt loam. Average percent slope at each location is indicated in Table 1.

Control of individual weed species was determined in the spring after complete snow melt by counting weeds in a 12- or 14-m^2 area in each plot and by visually rating percent control from 0 to 100 based on comparison with weed densities in nontreated check plots. Because species' response to herbicide treatments did not differ, weed control is reported collectively as total annual broadleaf weeds.

Weed infestations were generally light at all locations. Field pennycress (*Thlaspi arvense* L. #[3] THLAR) was the primary weed present at Location A, with an average of 34 plants per 10 m^2 in nontreated check plots. Common lambsquarters (*Chenopodium album* L. # CHEAL) and field pennycress were the predominant weeds at Location B, averaging 352 and 11 plants per 10 m^2 in nontreated check plots, respectively. Prickly lettuce (*Lactuca serriola* L. # LACSE) and snow speedwell (*Veronica campylopoda* Boiss.) were the most common weeds at Location C with an average of 34 and 5 plants per 10 m^2 in check plots. Location D had an average of 46 blue-eyed Mary (*Collinsia parviflora* Dougl. # CLCPA), 24 snow speedwell, and 15 prickly lettuce plants per 10 m^2 in nontreated plots.

Herbicide, UAN, and graphite tank mixes were evaluated for antagonistic or synergistic interactions in a greenhouse experiment. Six germinated lentil seeds (*Lens culinaris* Medik.) were planted June 25, 1987, in 0.5-L pots containing 350 g of air-dried sandy loam soil. Plants were grown with 14-h photoperiod of natural sunlight and average day/night temperature cycle of 26/18 C. Plants were thinned to four uniform seedlings approximately 6.5 cm tall 8 days after planting. Pots were arranged in a completely random design with treatments replicated three times. Herbicides were applied July 11 using a greenhouse spray chamber delivering 190 L/ha of spray at 210 kPa pressure. Herbicide, UAN, and graphite rates were the same as used in field experiments at Locations A and B. Plants were harvested Aug. 5, air dried, and weighed.

RESULTS AND DISCUSSION

Adding herbicide did not affect snow removal by graphite plus UAN 9 days after herbicide application for Location A, the site of greatest total snow cover

[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

Table 2. Average snow depth 9 days after application of herbicide, UAN[a], and graphite tank mixes to snow-covered plots, China Hat, ID.

Treatment	Rate	Snow depth
	(kg ai/ha)	(cm)
UAN	28	37.8
Graphite + UAN	20 + 28	12.5
2,4-D + dicamba + UAN	1.1 + 0.28 + 28	33.7
2,4-D + dicamba + UAN + graphite	1.1 + 0.28 + 28 + 20	15.3
Metsulfuron + UAN	0.0045 + 28	36.9
Metsulfuron + UAN + graphite	0.0045 + 28 + 20	15.6
Chlorsulfuron + UAN	0.018 + 28	36.9
Chlorsulfuron + UAN + graphite	0.018 + 28 + 20	13.1
LSD (0.05)		3.5

[a]Urea ammonium nitrate.

(Table 2). Graphite-related reductions in snow depth at the other three locations were similar 8 to 10 days after application. Averaged over all experiment locations, plots treated with graphite were snow-free 18 days earlier than plots without graphite (data not shown).

Sulfonylurea herbicides applied over snow in graphite plus UAN tank mixtures generally controlled annual broadleaf weeds, but equivalent 2,4-D plus dicamba treatments were ineffective (Table 3). Chlorsulfuron tank mixes controlled 95 to 100% of broadleaf weeds at all locations, and comparable metsulfuron treatments provided 89 to 100% control at three locations. The reason for reduced control with metsulfuron plus graphite at Location A is not known.

Weed control achieved from herbicides with graphite plus UAN applied over snow was equal to control from treatments applied in the fall to non-snow-covered winter wheat (Table 3). Chlorsulfuron and metsulfuron applied with or without graphite in the fall were 91 to 100% effective in controlling weeds, while equivalent over-snow treatments provided 92 to 100% control.

Adding graphite to sulfonylurea herbicide treatments appears essential to consistently control weeds with over-snow applications. The most dramatic example was at Location D, where percent weed control from chlorsulfuron and metsulfuron treatments was reduced from 98 and 92 when applied over snow with graphite to 8 and 5% control when applied without graphite (Table 3). Though differences were not as great, the phenomenon also was observed at Location A. Diminished weed control possibly resulted from a reduced amount of snow-applied herbicides actually reaching the soil surface. Strong winds occurring a few days after application at both Locations A and D significantly eroded surface snow from non-graphite plots, while appreciable snow erosion did not occur from graphite-treated plots. Wind erosion was not evident at Locations B and C. Surface snow displacement may correspond to herbicide loss and weed control reductions.

No crop injury was associated with any treatment nor was there evidence of antagonism or synergism among herbicides, UAN, and graphite in the field experiments. In the greenhouse study, average dry weights of lentils treated with tank-mix combinations of herbicide plus UAN, herbicide plus graphite, or herbicide plus UAN and graphite did not differ significantly from weights of lentils treated with a corresponding herbicide alone

Table 3. Annual broadleaf weed control by herbicides applied in fall to non-snow-covered and in winter to snow-covered plots.

Treatment	Rate	Snow-covered					Non-snow-covered		
		Location[a]					Location		
		A	B	C	D	Mean	C	D	Mean
	(kg ai/ha)	(%)					(%)		
UAN[b]	28	0	0	0	10	3	5	1	3
Graphite + UAN	20 + 28	0	0	0	0	0	0	3	2
2,4-D + dicamba + UAN	1.1 + 0.28 + 28	9	13	...	...	(11)	...	...	...
2,4-D + dicamba + UAN + graphite	1.1 + 0.28 + 28 + 20	20	8	...	...	(14)	...	...	...
Metsulfuron + UAN	0.0045 + 28	28	70	97	5	50	94	97	96
Metsulfuron + UAN + graphite	0.0045 + 28 + 20	40	89	100	92	80	97	91	94
Chlorsulfuron + UAN	0.018 + 28	78	90	93	8	67	99	100	100
Chlorsulfuron + UAN + graphite	0.018 + 28 + 20	95	100	100	98	98	100	99	100
LSD (0.05)		19	16	7	7	...	7	7	...

[a]Name of locations and primary weed species were A. China Hat, ID – field pennycress; B. Conda, ID – field pennycress and common lambsquarters; C. Cache Junction, UT – prickly lettuce and snow speedwell; and D. Pocatello Valley, ID – blue-eyed Mary, snow speedwell, and prickly lettuce.

[b]Urea ammonium nitrate.

Table 4. The influence of UAN[a], graphite and herbicide tank mixes on lentil dry weights.

Treatment	Rate	Lentil dry weight
	(kg ai/ha)	(mg)
2,4-D amine[b] + dicamba	1.1 + 0.28	45
2,4-D amine + dicamba + graphite	1.1 + 0.28 + 20	56
2,4-D amine + dicamba + UAN	1.1 + 0.28 + 20	63
2,4-D amine + dicamba + UAN + graphite	1.1 + 0.28 + 28 + 20	54
2,4-D ester[c] + dicamba	1.1 + 0.28	60
2,4-D ester + dicamba + graphite	1.1 + 0.28 + 20	63
2,4-D ester + dicamba + UAN	1.1 + 0.28 + 28	61
2,4-D ester + dicamba + UAN + graphite	1.1 + 0.28 + 28 + 20	56
Chlorsulfuron	0.018	70
Chlorsulfuron + graphite	0.018 + 20	99
Chlorsulfuron + UAN	0.018 + 28	70
Chlorsulfuron + UAN + graphite	0.018 + 28 + 20	63
Metsulfuron	0.0045	99
Metsulfuron + graphite	0.0045 + 20	80
Metsulfuron + UAN	0.0045 + 28	56
Metsulfuron + UAN + graphite	0.0045 + 28 + 20	78
UAN + graphite	28 + 20	196
UAN	28	161
Graphite	20	177
Check	...	202
LSD (0.05)		47

[a]Urea ammonium nitrate.

[b]Alkanolamine salt formulation of 2,4-D.

[c]2-ethylhexyl formulation of 2,4-D.

(Table 4). Dry weights of lentils treated with UAN, graphite, or UAN plus graphite without herbicide did not differ from the nontreated check.

These studies demonstrate the feasibility of combining chlorsulfuron or metsulfuron with conventional graphite snow-removal treatments in winter wheat to control weeds and snow mold in a single operation. However, applying either herbicide over snow is expressly prohibited on the product labels. Further study of herbicide movement and environmental fate is required before the practice could be adopted.

ACKNOWLEDGMENTS

This research was partially supported by Superior Graphite Co., Utah Agric. Exp. Stn., and USDA Ext. Serv.

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AGRONOMIC MODIFICATIONS OF A DRYLAND WINTER WHEAT ENVIRONMENT RESULTING FROM GRAPHITE-NITROGEN APPLICATION TO SNOWPACK[1]

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ABSTRACT

Graphite, in an aqueous nitrogen (N) suspension of urea ammonium nitrate (UAN), was applied to snowpack covering dryland winter wheat in either February or March to determine impacts on wheat yield, soil temperature, available soil moisture, and N movement in soil in these wheat cropping systems. Field plots were established in the Pocatello Valley and Soda Springs areas of southern Idaho. Both experiments were located on soils with slopes of 1-2%. Snow depths ranged from 40-65 cm at treatment application. Neutron activation determined soil water and thermocouples measured soil temperature in each plot following snowmelt from control plots. Soil water differences were observed between the graphite treatment and the check to a soil depth of 90 cm in the spring. Soil temperature fluctuation following snowmelt was more excessive when the graphite influenced snow melt. There was a tendency for higher soil temperatures (above 0^{o} C) initially with the graphite treatments. These higher temperatures were observed for over 20 days longer than the control and to a depth of 20 cm. Increased wheat yields were observed above similar fall or spring N application treatments. These treatments were likely influenced by increased soil temperature and soil water content as a function of controlled (pulsed) snow melting with graphite.

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1. Journal article No. _____, Idaho Agricultural Experiment Station.
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INTRODUCTION

Graphite has been used to hasten snowpack melt in the spring in wheat producing areas of Idaho and other western states. It was originally used to decrease the incidence of snow mold in winter wheat (Fischer and Bruehl, 1964, Bruehl et al., 1965, Cartee, et al., 1987, and Tindall 1986). The treatment was modified to include urea ammonium nitrate (UAN) with the graphite to provide N fertilizer. The UAN was an effective alternative to water as a carrier solution for the graphite, and decreased the susceptibility of the spray to freezing during cold temperature applications. (Tindall, 1986 and Tindall and Dewey, 1987)

When a graphite suspension is applied to the snow surface, the graphite intercepts net solar radiation resulting in increased temperature in the micro-environment immediately surrounding the dark graphite particles. This temperature increase results in significant melting of the adjacent ice/snow crystals. This occurs even when air temperatures are below zero degrees C snow melt can be complete before normal spring thaw. Snow is melted a only during periods of solar radiation (unless the air temperature increases above freezing) and re-freezes at night resulting in a controlled, more gradual, pulse melt (Gavlak et al., 1988). Normal spring melting, which occurs when the usual ambient air temperature is above freezing, is much more rapid and results in greater surface runoff.

Rapid snow melting from graphite exposes the soil surface up to 15 days earlier than the control. The result is an increase in heat units available to the growing wheat. Plants which have been exposed earlier as a result of pulsed rapid snow melt tend to respond with greater productivity even when diseases are not a factor. This research was conducted to determine the effects of early temperature and moisture modifications on yield of winter wheat and N-use efficiency of fertilizer N applied to the snow surface.

MATERIALS AND METHODS

Field plots were established in the fall of 1988/89 on dryland winter wheat (*Triticum aestivium* L., cv. Manning) in the Pocatello Valley and Soda Springs areas of southern Idaho. The soils in Pocatello Valley are Parleys silt loam on 1-2% slope (fine-loamy mixed mesic

Typic Argixeroll), and in Soda Springs a RIN very fine sandy loam (coarse-silty Pachic Cryoboroll). The experiments for each location were randomized complete blocks with 14 treatments and 4 replications. Nitrogen treatments (UAN) were 28, 56, 112, and 224 kg N ha^{-1} applied preplant incorporated in the fall or broadcast in the spring after snowmelt or applied with 20 kg ha^{-1} 20 micron size graphite to snowpack ranging from 46 cm at the Pocatello site to 71 cm at the Soda Springs site in February. Graphite treatment were applied as a UAN suspension using a small plot CO_2 type backpack sprayer. After many attempts to perfect a suitable application technique it was concluded that wearing snowshoes or cross-country skies was the most reliable. The UAN solution was diluted in the winter to 28% N to avoid precipitates forming as temperatures were below freezing. Spring broadcast N applications were made in both locations immediately after complete snowmelt from all plots. In November, prior to any snow accumulations, thermocouples were placed in both the 112 kg ha^{-1} fall and the snowpack-graphite treated plots at depths of 5, 10, and 20 cm. The thermocouples were attached to a *Campbell Scientific 21-X* data logger with temperatures taken every 20 minutes with the 24 h mean recorder. Temperatures were recorded until differences between treatments were no longer observed. Data files were retrieved and stored on a portable computer weekly.

To measure changes in available soil water over the growing season, neutron probe access tubes were placed in plots with thermocouples. Soil water content was measured to 90 cm at 15 cm increments throughout the growing season with the neutron probe.

A 1 by 12 m section of each plot was harvested at plant maturity with a *Massey* small plot harvester and grain yields determined for both locations.

RESULTS AND DISCUSSION

Snowmelt was accelerated by the graphite treatments similarly to results reported by Tindall (1986) and Tindall and Dewey (1987). When the graphite treated areas were bare, 50% of the original snowpack remained on the graphite-free plots. Snow remained approximately 14-20 days longer on the areas.

Soil Temperature Modification

Soil temperature at the 5 cm depth in 1988 at Soda Springs are shown in Fig. 1 (10 and 20 cm not shown). Soil temperature differences were measured at 5, 10 and 20 cm for 38 days beginning when graphite treated plots were bare. The snow pack overlying winter wheat in 1988 was less than average, consequently the snow melted more rapidly exposing the soil earlier than previous years. Soil temperatures on the graphite treated areas were elevated above the control, due to early snow melt. Because of this early snowmelt there appears to be greater fluctuations in soil temperatures relative to the ambient air temperatures.

Soil temperature levels for Soda Springs and Pocatello Valley areas in 1989 are also indicated in Fig. 1. Soil temperature data were collected at 5, 10, and 20 cm (10-20 cm not shown) beginning on Julian Day 67 and ending on day 105. The mean daily soil temperatures for Soda Springs during experiment seldom dropped below zero degrees C. Soil temperatures in the graphite treated plots were as much as a 2 degrees higher than in control plots between days 83 and 86 at the 5 cm depth. Soil temperature was higher (than what) at the 20 cm soil depth with less fluctuations due to air temperature changes. At the Soda Springs location at day 95 both control and graphite temperatures were the same at the 20 cm soil depth (data not shown). This indicates about a 20 day difference in elevated soil temperatures at the Soda Springs location even at a 20 cm depth. Similar differences were observed for the Pocatello Valley plots in 1989. However, there were greater fluctuations in soil temperatures with the graphite treated plots at Pocatello Valley. The bare soil temperature dropped to -7^{o} C on day 74 at both 5 and 10 cm with a drop to -10^{o} C at 20 cm. The 20 cm reading generally had lower soil temperatures because of less fluctuation compared to the 5 cm reading. If 0 degrees C is used as a critical soil temperature prior to wheat growth, the temperature data indicate several more days where the soil temperature is above this critical level in graphite-treated plots compared with the soil temperature of the control. This may help explain part of the yield increases noted when graphite is used in wheat production systems and disease is not a yield limiting factor.

Soil Water Modification

Tables 1-2 indicate soil water content in the spring of 1989 at Soda Springs and Pocatello Valley to a depth of 90 cm. The available soil water levels are somewhat difficult to interpret. Soil water content with graphite was significantly greater than the control on 3/15 at all but the surface of the measured soil profile at Soda Springs in 1989. This time frame would be 2-days after soil exposure from the graphite treatments. The Soda Springs location had more snowpack than the Pocatello Valley, there was an increase in soil water moving into the soil to a greater extent with graphite. However, 5 days after the initial reading there was no significant difference in soil water content to 30 cm. By 3/23 the graphite treatments had significantly less soil water than the control in the top 46 cm. However, at lower depths for both locations there was a greater percent of available water with the graphite application. This relates closely to when these plots were bared of snow. After 3/27 there was measurable difference in available soil water for the graphite treated areas over the control at the deeper depths (61-91 cm). The Pocatello Valley area had less snow and did not exhibit any appreciable difference in available soil water related to snow applied graphite applications. In those areas where there is a soil water difference growers might take advantage of these conditions by being able to work these soils earlier in the spring with less compaction concerns, but the time frame for this difference, although significant, is of relatively short duration.

NITRATE AND AMMONIUM MOVEMENT

Tables 3 and 4 provide soil nitrate and ammonium (inorganic N) levels from Soda Springs and Pocatello Valley. These samples were collected at heading and reflect N movement through the soil related to N application timing. The greatest surface inorganic N was detected from the spring application. The lowest soil inorganic N is for the fall applied N treatments. The over snow applied N with graphite treatment had greater concentrations of N at 30-60 cm than either the fall or spring applied treatments. It would appear that the fall treatment is the least effective way to apply N in these areas. The snow applied N treatments with graphite and spring N application have more N within the soil system than the fall application. The snow application has the greatest amount of recoverable nitrate at lower depths than either the fall or the spring N treatments. This movement rate would indicate the pulse rate of snow melt has the capacity to move greater nitrate concentrations into the lower root zone. The surface residual levels of NH_4-N increase as the level of N fertilizer increases. The highest soil NH_4-N level was for the spring N applications. This was true when each of the timing applications were made and for most of the depths. This is probably attributed to the dry soil conditions not allowing mineralization. The over snow application of N with graphite indicated more available N at lower depths compared to the fall treatments for both locations and for both years. When compared to the spring treatments the level of available NO_3-N and NH_4-N are less for the 0-15 cm depths, but comparable for the spring treatments if not slightly lower.

The historical N application rate for these wheat producing areas is between 56 and 112 kg ha^{-1} N (Tindall, et al., 1991). For these application levels it would appear that over snow application of N would be an alternative N application management program. There is no significant loss of N with this type of application procedure for the 56 kg ha^{-1} application rate. As the N concentration is increased to 112 kg ha^{-1} there appears to be an advantage to snow applied over the fall application in recoverable nitrate levels. The spring application has very little moisture to move the N into the soil profile, therefore higher nitrate concentration levels were measured in the surface compared to either fall or over snow applications.

YIELDS

Grain yields for the Soda Springs and Pocatello Valley sites for 1988-89 are indicated in Table 7. Values are expressed in percent of yield above the control. Yields for Soda Springs area are the means of two site locations for both 1988 and 1989. Yield levels for Soda Springs are consistent for both years with the largest percent in yield associated with the over snow application of N with graphite and the spring application of N. The fall application of N at the higher levels (224 kg ha^{-1}) of N was comparable to the winter over snow and the spring application, but crop response to the lower levels of N applied in the fall were considerably lower. This was probably due to the leaching of NO_3N related to over winter precipitation. Yield levels for the Pocatello Valley plots had tremendous variability between 1988 vs 1989. The 1988 yields were very much a reflection of below normal precipitation for the growing season. The greatest yield suppression came with the highest N fertilizer application Yields for any treatment were below historical means. The only treatments that appeared higher than the control were over snow application of N with graphite at either 28 or 56 kg ha^{-1} rates, but these were not significant. There were many treatments which were significantly lower than the control by several percent, but these values are a reflection of poor precipitation and low stored soil water levels. The 1989 yield levels for Pocatello Valley indicated a favorable response to the graphite-N application to snowpack covering the winter wheat. This particular treatment provided the highest yield with levels of 165% above the control. Yield responses in the Soda Springs area were also increased above the control with the graphite application.

CONCLUSIONS

A graphite-N application technique appears to be a viable alternative to a traditional N management program for dryland winter wheat in the Intermountain West. The success is dependent on the depth of snow and soil conditions prior to application. Although disease control was the original basis for application, this research indicates benefits when disease is not a factor in production. Factors which might explain the increased yields would be more available water at deeper depths and a greater efficiency of N when applied in combination with the graphite over snow. There appears to be a more rapid movement of N into the root zone with ample moisture levels for the wheat plants to utilize the N with pulse melt from the graphite. However, if snow pack is low or less than a critical level the N with the graphite is ineffective. There is a positive indication that soil temperature, which is increased early in the growing season because of the controlled snowmelt, in combination with N movement into the soil profile with pulse melting provides a basis for the increased productivity in most years.

Negative aspects of a graphite N application over snow would be the need for new equipment development and application of the graphite-N material during the winter months when conditions are anything but ideal. Other considerations include the variability of the snowpack which may not last for extended periods of time and the potential movement of N off of steeper slopes during spring runoff. Dewey et al., 1989 and Asghari et al., 1989 indicated that certain herbicides when combined with the graphite and applied to slopes up to 10% resulted in little downslope movement. This last variable concerning nitrates has not been studied and remains for a future research program.

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Table 1. Soil water content over time, depth and applied graphite at Soda Springs, 1989.

Soil Depth (cm)	Graphite[a] Treatment	1989 Sampling Date 3/15	3/20	3/23	3/27	3/31	4/3	4/7	4/11	Total
		% Available Water								
0-15	+	29.5	29.8	*27.9	*26.6	26.8	27.4	27.3	28.2	196.1
	-	28.1	29.8	29.2	28.0	28.0	28.1	28.6	28.9	228.7
15-30	+	*29.9	30.1	28.6	28.8	28.5	29.5	30.6	29.5	264.3
	-	26.5	29.0	30.0	29.5	29.5	29.6	30.0	29.1	233.2
30-46	+	*30.1	*30.0	30.9	29.9	30.2	30.1	30.5	30.4	242.1
	-	24.9	28.3	31.0	30.9	30.0	29.3	29.3	29.4	233.1
46-61	+	*29.7	*29.8	31.8	31.5	31.8	31.8	32.0	31.9	250.3
	-	25.3	28.0	31.3	32.3	30.6	30.5	30.7	31.9	240.6
61-76	+	*29.5	*29.6	*32.1	31.8	31.9	31.5	31.9	*32.6	250.9
	-	25.6	27.9	30.6	31.1	31.2	31.4	30.4	30.4	238.6
76-91	+	*31.3	*30.0	*32.7	*32.1	*32.5	*32.6	*32.2	*33.2	256.6
	-	26.0	27.8	29.6	29.6	29.3	29.6	30.2	30.4	232.5
LSD (0.05)		1.4	1.0	1.4	1.3	1.4	1.5	1.8	1.8	

[a]Graphite applied at 20 kg ha^{-1} on the snow surface; bare ground for graphite treatments occured on 3/23.
*Significantly different at .05% level.

Table 2. Soil water content over time, depth and applied graphite at Pocatello Valley, 1989.

Soil Depth (cm)	Graphite[a] Treatment	1989 Sampling Date 3/15	3/20	3/23	3/27	3/31	4/3	4/7	4/11	Total
		% Available Water								
0-15	+	29.8	28.4	28.0	27.7	27.8	27.5	28.3	28.0	225.5
	-	29.0	29.1	29.8	28.7	30.1	29.5	29.3	29.9	235.4
15-30	+	29.7	29.8	29.6	28.7	28.6	28.8	28.4	29.1	232.7
	-	29.7	29.8	30.1	29.7	30.8	31.3	31.0	31.3	242.8
30-46	+	31.0	30.9	30.7	30.1	29.9	29.9	30.1	30.6	243.2
	-	30.2	30.7	31.5	31.3	32.2	32.7	31.9	32.4	252.9
46-61	+	31.4	31.5	32.2	31.6	31.8	31.7	31.3	31.9	253.4
	-	28.9	29.9	31.6	32.6	31.7	31.9	30.6	31.2	248.4
61-76	+	*30.7	*31.4	32.5	32.0	32.0	31.6	*31.9	32.4	254.5
	-	25.6	28.1	29.7	30.7	29.7	29.7	29.3	29.8	232.6
76-91	+	*30.6	*31.6	*33.0	*32.0	*32.1	*32.3	*32.4	*32.8	256.8
	-	24.0	26.7	29.1	29.4	28.8	28.0	29.0	27.8	222.8
LSD (0.05)		2.6	2.5	2.2	2.3	2.5	2.5	2.3	2.6	

[a]Graphite applied at 20 kg ha^{-1} on the snow surface; bare ground for graphite treatments occured on 3/23.
*Significantly different at .05% level.

Table 3. Nitrate and ammonium levels in soil with fall (F), winter over snow with graphite (Sn), and spring applied (Sp) N to winter wheat at Soda Springs, 1988

Treatment (N) (kg ha $^{-1}$)	Soil Depth (cm) 0-15 NO_3-N	0-15 NH_4-N	15-30 NO_3-N	15-30 NH_4-N	30-60 NO_3-N	30-60 NH_4-N	60-90 NO3-N	60-90 NH4-N	$\bar{X}$
0	2.88	4.75	2.63	4.50	2.63	4.25	2.50	4.50	3.58
28 F	4.50	4.50	5.00	4.25	4.50	4.50	5.00	4.75	4.63
56 F	4.63	5.25	2.75	5.00	2.38	4.25	2.63	4.50	3.92
112 F	5.75	7.00	7.00	7.00	4.38	5.00	4.63	5.50	5.78
224 F	12.38	8.50	8.50	8.50	6.75	5.25	6.75	5.75	7.80
28 Sn	5.12	4.75	3.88	4.00	3.25	4.00	2.88	4.75	4.07
56 Sn	6.88	5.50	4.50	5.25	4.13	4.50	2.88	4.50	4.77
112 Sn	11.25	6.38	6.88	5.00	8.12	4.00	3.75	3.25	6.08
224 Sn	14.12	7.50	13.75	5.75	2.38	4.00	4.00	4.75	7.03
28 Sp	6.00	13.75	3.75	6.75	2.75	5.75	2.50	4.50	5.72
56 Sp	7.88	6.50	4.88	5.00	3.00	5.00	2.50	4.50	4.91
112 Sp	12.25	11.50	6.38	5.25	3.63	5.00	2.50	4.75	6.41
224 Sp	23.88	16.50	8.88	5.25	3.00	4.75	3.37	4.50	8.766

LSD (0.05) for Depth of NO_3-N = 1.55/LSD (0.05) for Treatment of NO_3-N = 2.76
LSD (0.05) for Depth of NH_4-N = 3.02/LSD (0.05) for Treatment of NH_4-N = 5.76

Table 4. Nitrate and ammonium levels in soil with fall (F), winter over snow with graphite (Sn), and spring applied (Sn) N to winter wheat at Pocatello Valley, 1988

Treatment (N) (kg ha $^{-1}$)	Soil Depth (cm) 0-15 NO_3-N	0-15 NH_4-N	15-30 NO_3-N	15-30 NH_4-N	30-60 NO_3-N	30-60 NH_4-N	60-90 NO3-N	60-90 NH4-N	$\bar{X}$
0	4.25	5.25	3.12	5.75	2.38	5.00	2.63	4.00	4.05
28 F	4.00	5.00	2.75	5.75	1.25	6.00	1.50	5.50	3.97
56 F	4.63	4.50	4.38	6.25	4.25	2.75	3.14	4.25	4.05
112 F	8.91	6.25	6.00	6.38	4.50	6.00	3.00	5.00	5.76
224 F	13.21	7.25	7.38	7.50	9.63	7.25	6.25	4.00	7.81
28 Sn	10.00	4.75	4.50	5.50	2.75	5.50	2.75	7.25	5.38
56 Sn	6.63	8.00	4.63	7.75	6.88	7.50	2.55	7.00	6.37
112 Sn	11.25	10.00	8.50	8.75	7.65	8.75	5.12	7.25	8.40
224 Sn	19.25	12.50	10.63	12.75	10.38	10.00	6.12	10.25	11.49
28 Sp	4.63	6.25	3.13	4.50	2.25	4.75	1.37	4.75	3.95
56 Sp	9.75	9.25	6.63	5.00	5.00	4.00	2.87	4.50	5.88
112 Sp	11.88	11.50	11.37	4.75	5.50	4.75	2.63	4.50	7.11
224 Sp	25.00	16.00	14.87	5.25	10.75	4.75	4.12	5.00	9.07

LSD (0.05) for Depth of NO_3-N = 1.3/LSD (0.05) for Treatment of NO_3-N = 4.8
LSD (0.05) for Depth of NH_4-N = .8/LSD (0.05) for Treatment of NH_4-N = 2.8

Table 5. Nitrate and ammonium levels in soil with fall, winter over snow with graphite, and spring applied N to winter wheat -- Soda Springs, 1989

Treatment (N) (kg ha $^{-1}$)	Soil Depth (cm) 0-15 NO_3-N	0-15 NH_4-N	15-30 NO_3-N	15-30 NH_4-N	30-60 NO_3-N	30-60 NH_4-N	60-90 NO3-N	60-90 NH4-N	$\bar{X}$
0	2.63	4.75	2.63	5.00	2.63	4.75	2.38	4.50	3.66
28 F	7.50	8.25	6.38	7.00	2.88	7.50	2.88	7.50	6.24
56 F	5.38	4.25	3.38	5.00	2.50	4.00	2.38	4.25	3.89
112 F	7.50	10.50	6.38	8.50	2.88	7.75	2.88	8.75	6.89
224 F	19.75	10.50	14.38	12.00	8.63	8.00	8.25	7.00	11.06
28 Sn	14.50	9.75	7.13	7.50	4.25	6.00	3.50	4.50	7.14
56 Sn	11.25	13.00	6.13	9.75	3.88	7.25	3.50	5.25	7.50
112 Sn	11.25	27.25	7.13	19.00	4.88	11.00	5.38	7.50	11.67
224 Sn	30.87	94.75	18.88	34.75	11.13	12.75	6.50	6.75	27.05
28 Sp	10.00	14.00	9.50	9.75	2.75	5.00	2.25	4.50	7.22
56 Sp	12.63	30.75	11.50	15.50	4.25	6.00	1.75	4.50	10.86
112 Sp	26.75	67.00	12.88	23.75	4.63	8.50	2.63	5.75	18.99
224 Sp	68.50	136.25	38.50	62.75	10.13	24.25	6.63	8.75	44.47

LSD (0.05) for Depth of NO_3-N = 2.04/LSD (0.05) for Treatment of NO_3-N = 3.95
LSD (0.05) for Depth of NH_4-N = 3.95/LSD (0.05) for Treatment of NH_4-N = 7.65

Table 6. Nitrate and ammonium levels in soil with fall, winter over snow with graphite, and spring applied N to winter wheat -- Pocatello Valley, 1989

Treatment (N) (kg ha $^{-1}$)	Soil Depth (cm) 0-15 NO_3-N	0-15 NH_4-N	15-30 NO_3-N	15-30 NH_4-N	30-60 NO_3-N	30-60 NH_4-N	60-90 NO3-N	60-90 NH4-N	$\bar{X}$
0	4.63	5.25	4.50	5.75	3.75	5.00	3.75	5.00	4.70
28 F	9.88	8.75	5.38	6.75	5.88	8.25	3.88	9.00	7.22
56 F	8.63	8.50	4.88	10.25	4.63	7.00	4.25	8.25	7.04
112 F	22.13	14.00	9.13	10.25	4.75	12.25	4.25	12.00	11.10
224 F	19.13	19.25	9.50	19.50	13.63	19.25	6.25	17.50	15.50
28 Sn	10.75	10.75	8.00	8.00	5.50	9.25	4.25	8.50	8.13
56 Sn	11.75	12.00	8.25	9.50	4.87	12.00	4.00	11.00	9.17
112 Sn	14.13	21.25	10.00	13.50	5.38	12.25	4.63	11.75	11.61
224 Sn	35.75	82.50	13.50	14.85	6.88	18.75	5.62	12.75	23.83
28 Sp	11.00	15.50	5.38	13.50	4.00	9.00	3.88	9.00	8.91
56 Sp	16.50	33.00	7.00	16.00	4.50	13.75	4.00	10.75	13.19
112 Sp	25.00	42.50	11.38	24.25	5.75	15.25	4.00	15.75	17.99
224 Sp	49.25	102.25	14.88	41.75	6.12	16.50	4.38	18.50	31.70

LSD (0.05) for Depth of NO_3-N = 1.56/LSD (0.05) for Treatment of NO_3-N = 3.01
LSD (0.05) for Depth of NH_4-N = 3.34/LSD (0.05) for Treatment of NH_4-N = 6.47

Table 7. Yield of dryland winter wheat from Soda Springs and Pocatello Valley with graphite[a] and N applied in the fall over snow or spring for 1988-89.

Treatments[b]	Soda Springs		Pocatello Valley	
N (kg ha $^{-1}$)	88	89	88	89
	% above control			
0 N w/graphite	13.1	30.2	2.8	15.1
28 N Fall	21.0	24.2	-17.1	12.8
56 N Fall	13.8	62.1	-17.1	21.2
112 N Fall	8.7	45.5	-27.1	50.5
224 N Fall	6.1	82.2	-36.4	141.7
28 Snow	33.3	70.2	5.2	62.9
56 Snow	38.9	84.6	7.5	67.3
112 Snow	52.9	85.7	-10.1	165.6
224 Snow	16.2	83.6	-37.9	151.4
28 N Sp	14.2	55.4	-15.6	14.2
56 N Sp	32.3	71.2	-17.9	26.0
112 N Sp	10.4	86.6	-18.8	74.1
224 N Sp	5.9	85.2	-33.5	133.2
LSD (0.05)	17.3	16.8	25.3	41.2

[a]Graphite was applied only on the over snow application.
[b]Nitrogen treatments applied at Urea ammonium nitrate.

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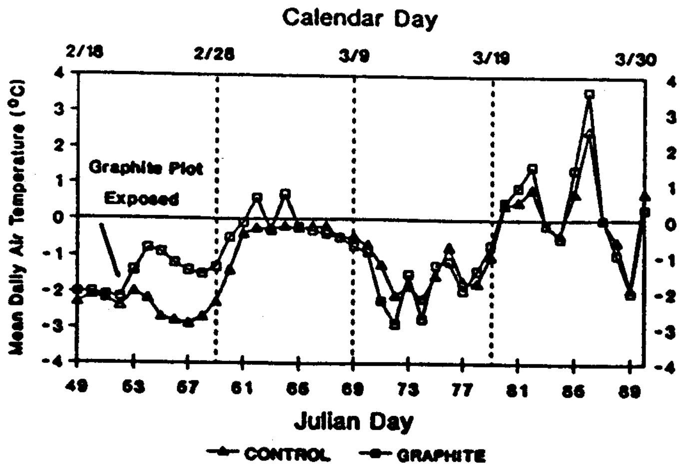
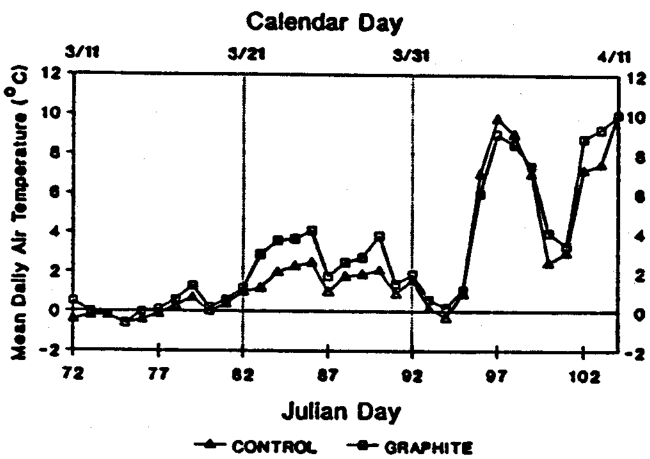
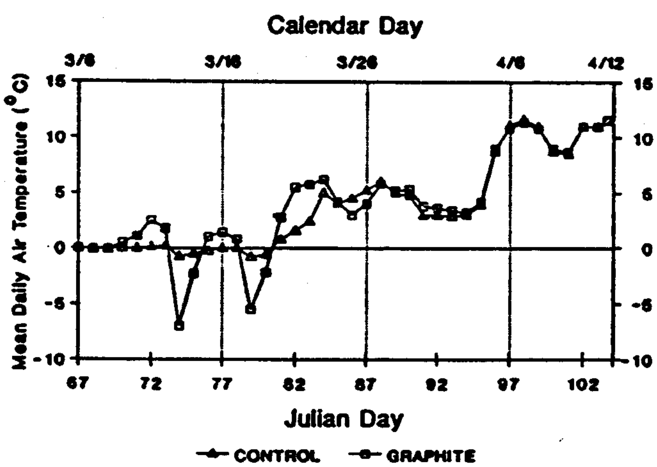


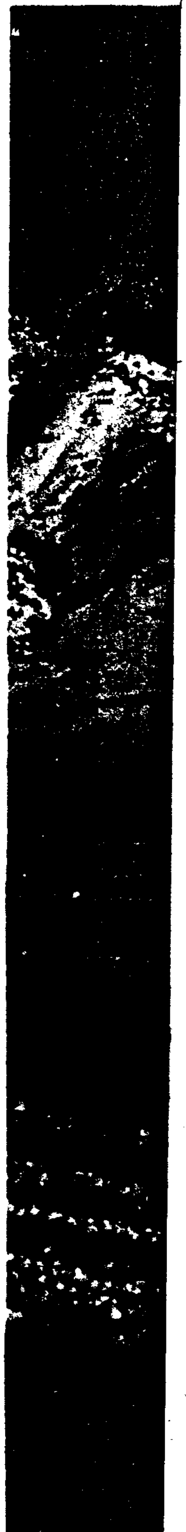
Soil temperature modification under winter wheat from graphite at 5 cm in Soda Springs, ID, - 1988



Soil temperature modification under winter wheat from graphite at 5 cm in Soda Springs, ID, — 1989



Soil temperature modification under winter wheat from graphite at 5 cm in Pocatello Valley, ID, — 1989



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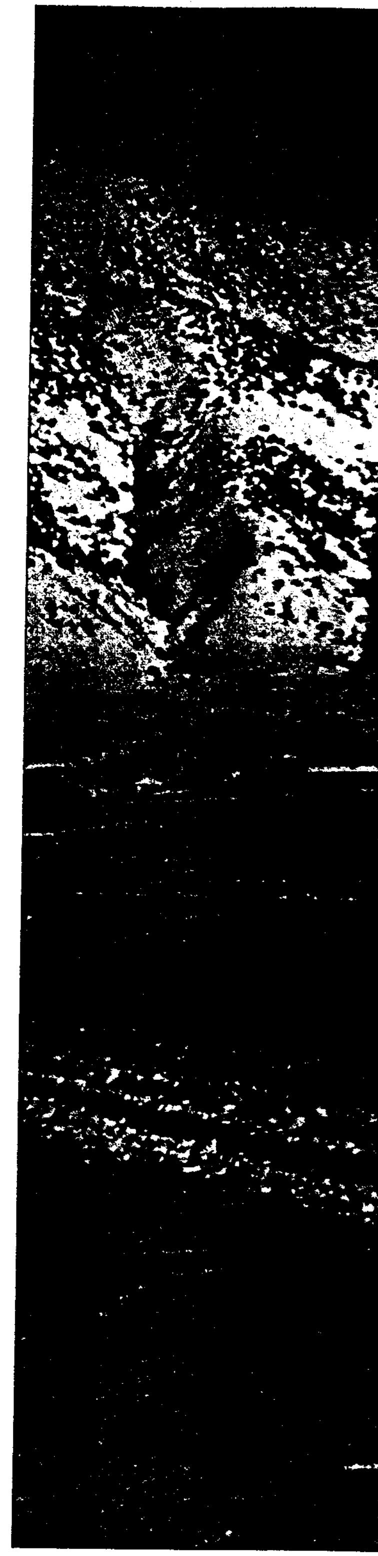
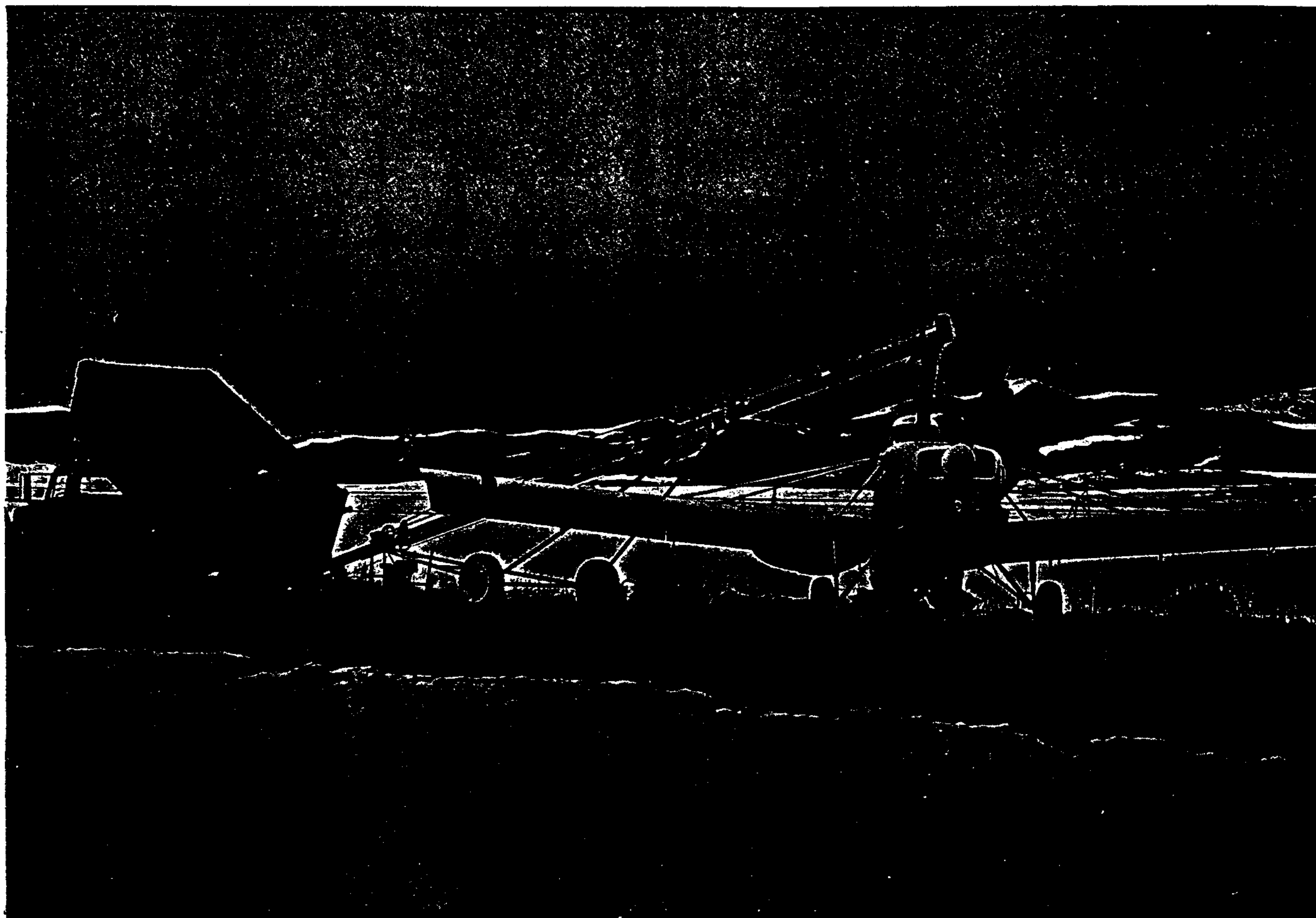
CONTROLLING SNOWMOLD IN DRYLAND WHEAT

R. L. CARTEE, R. F. NIELSON, and T. A. TINDALL



Snowmold in dryland winter whe
grown in northern Utah and
southern Idaho has caused millions
dollars of damage annually in reduc
yields and costs of replanting (Nielso
and Cartee 1976). The disease is ca
by the widespread organisms *Typhu*
and *Fusarium*. Mold damage is
increased when the snow is deep
enough (one foot or more) to insula



Loading furnace ash into an airplane.

Loading furnace ash into a spreader mounted on a Snow Cat.

Under the right conditions, furnace ash can rapidly decrease snow depth.

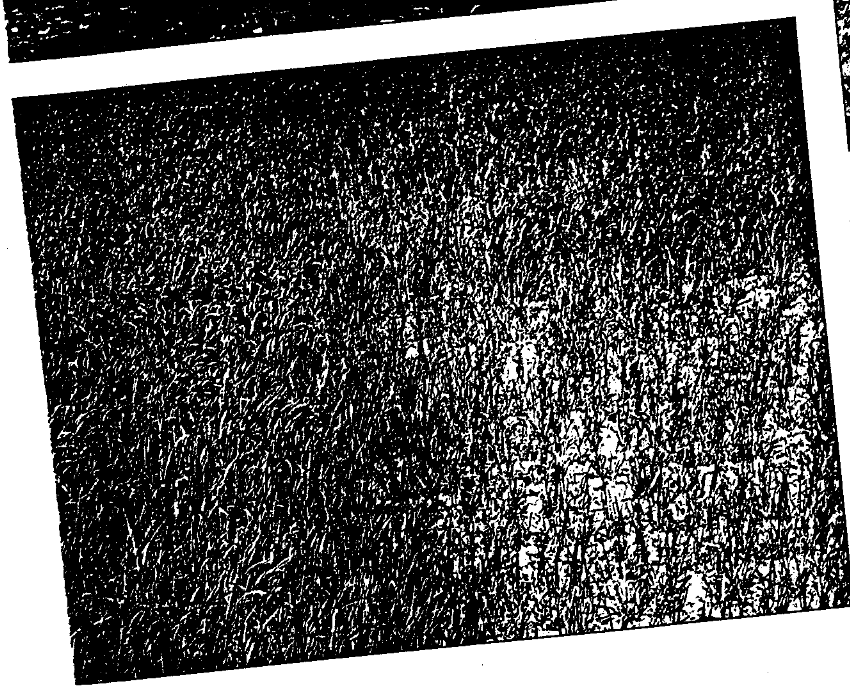
There was no visible snowmold damage on this field treated with furnace ash. Note the snow cover on the untreated land around the field.

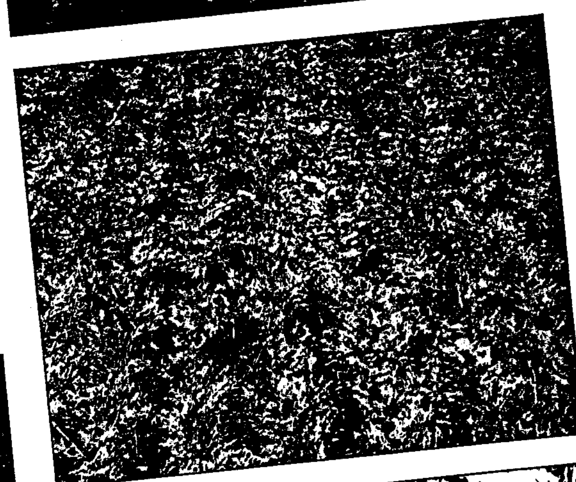
E. Snowmold spores and wheat plants killed by the organism.

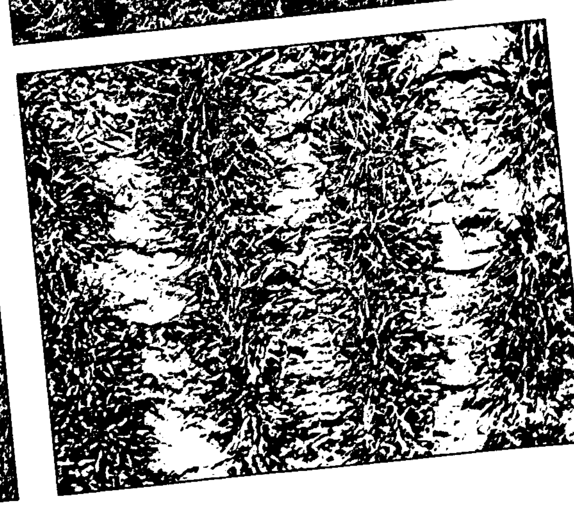
F. Healthy winter wheat with very little snowmold damage.

G. Note the difference in the stand of wheat between the area treated with darkening agent (left) and the untreated area (right).


Turbo
Thiokol







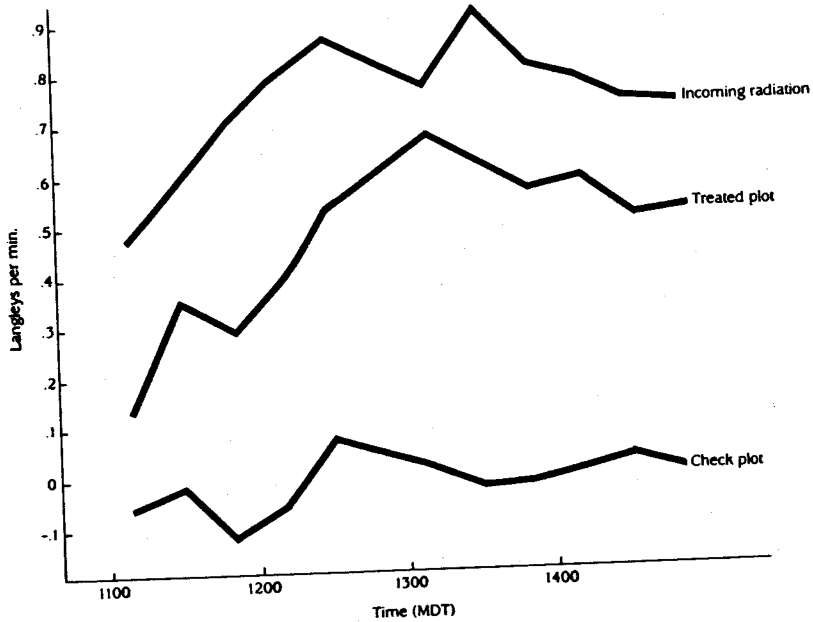


FIGURE 1. Radiation absorption on untreated plots and plots treated with ash.

Bluecreek Experimental Farm in Box Elder County.

Furnace Ash

During 1970-73, furnace ash from the coal-fired heating plant at USU was applied (200 lb. per acre) by an airplane. Treatment accelerated snow melt, and reduced the incidence of snowmold. In the fall of 1973 a fertilizer spreader mounted on a sleigh pulled by a snowmobile was used to apply the ash in more detailed studies of the effects of timing, frequency and rate of application.

Application of a blackening agent such as furnace ash darkens the snow surface; more incoming solar radiation is absorbed, thus melting the snow even though air temperatures may be freezing or below. White, untreated snow surface reflects solar radiation. Figure 1 compares radiation absorbed by treated and untreated plots at midday. The treated area absorbed considerable incoming radiation while the untreated area absorbed almost none. Application of less than 150 lb. of ash per acre did not darken snow enough while applying over 200 lb. per acre did not increase absorption. This indicated that the optimum amount of ash to apply was between 150 and 200 lb. per acre.

Table 1 compares snowmelt on treated and untreated areas from 1975 through 1985. The untreated areas remained under snow longer than those treated with ash. In some years, soil under snow was not frozen. Both snow cover and unfrozen soils contributed to severe snowmold damage.

Table 2 shows yield and percentage protein on experimental plots. Except in 1977, applying ash significantly increased wheat yields. During 1975-77, the protein content of the wheat variety (Hansel) remained constant or increased in the treated areas. The wheat variety in subsequent years was Manning. Except in 1982, protein content decreased in the treated areas because yields increased considerably. Protein content of Manning tends to decrease as yields increase, however, Cartee et al. (1986) found that protein level can be maintained with high yields if additional nitrogen is applied in the spring. In 1977, soils were covered late in the winter by about 10 inches of snow and remained frozen during the remainder of winter. Consequently, treatment did not significantly increase yields because snowmold damage was slight. Therefore, ash was not applied in 1980 and 1981 when conditions were similar.

In 1976, USU cooperated with Thiokol Corporation (Snow Cat Division) in mounting a sand spreader on a large snow-cat to apply ash on plots at four locations in northern Box Elder County. The results (Nielson and Cartee 1976) were similar to those at the Blue Creek Experimental Farm during 1976 (Table

TABLE 1. Comparison of snowmelt on control plots and plots treated with fly ash (Bluecreek Experimental Farm).

	Treated		Untreated		
	Continuous days under snow		Continuous days under snow		Reduction in days under snow with treatment
Year	Total	No soil frost	Total	No soil frost	
1975	65	22	85	42	20
1976	90	90	118	118	28
1977	40	0	48	0	8
1978	63	30	83	50	20
1979	102	64	126	88	24
1980	— Ash not applied —				
1981	— Ash not applied —				
1982	68	68	86	86	16
1983	104	70	128	94	24
1984	100	62	117	79	17
1985	80	61	101	82	21
Average	79	52	99	71	20

2). Snowmold damage decreased and yields increased by 50 to 70 percent where ash was applied. Following this study, commercial application of darkening agents began, primarily using ash from coal-fired power plants.

Table 3 presents an economic evaluation of ash application. Income per acre, based on the price per bushel at harvest, was adjusted for protein and yield. The net income per acre was calculated by adding the income from the untreated plots to the cost of applying ash. This sum was then subtracted from income from treated plots. Except in 1977 when snow cover was light and soils remained frozen, applying ash increased net income.

TABLE 2. Yield and protein content of wheat from control plots and plots treated with fly ash (Bluecreek Experimental Farm).*

	Yield (bu/A)				Protein (%)			
Year	Treated	Untreated	Difference	LSD**	Treated	Untreated	Difference	LSD**
1975	51.2	43.0	8.2	2.4	15.7	13.9	1.8	0.4
1976	41.2	19.8	21.4	3.4	14.8	13.6	1.2	0.5
1977	58.5	56.2	2.3	2.8	8.9	8.9	0	0.6
1978	53.8	36.5	16.3	1.9	10.2	11.0	-0.8	0.5
1979	42.7	22.7	20.0	2.3	10.6	13.8	-3.2	0.7
1980	— Ash not applied —							
1981	— Ash not applied —							
1982	58.1	32.0	26.1	3.6	10.9	10.4	0.5	0.6
1983	53.6	33.1	20.5	2.7	10.8	12.1	-1.3	0.4
1984	49.9	29.2	20.7	2.1	11.2	11.8	-0.6	0.3
1985	58.0	30.4	27.6	3.1	10.5	12.0	-1.5	0.8
Average	51.9	33.7	18.2	2.7	11.5	11.9	-0.4	0.5

*All plots were fertilized with 50 lb. N/A as anhydrous ammonia in the fall.
**Least significant difference at 0.05 confidence level.

[ABLE 3. Yields, protein content, and returns on control plots and plots treated with fly ash (Bluecreek Experimental Farm).

(ear	Untreated bu/a	Untreated Protein (5)	Untreated Income/a	Treated bu/a	Treated Protein (%)	Treated Income/a	Cost/a of applying ash	Net increase in income per acre due to application of ash
1975	43.0	13.9	$190.92	51.2	15.7	$245.76	$ 6.00	$48.84
1976	19.8	13.6	86.72	41.2	14.8	190.34	6.00	97.62
1977	56.2	8.9	185.46	58.5	8.9	193.05	6.00	1.59
1978	36.5	11.0	133.23	53.8	10.2	188.30	12.00	43.07
1979	22.7	13.8	100.33	42.7	10.6	151.59	12.00	39.36
1980					— Ash not applied —			
1981					— Ash not applied —			
1982	32.0	10.4	112.32	58.1	10.9	210.90	7.00	91.58
1983	33.1	12.1	135.05	53.6	10.8	193.50	7.00	51.45
1984	29.2	11.8	115.34	49.9	11.2	184.63	14.00	55.29
1985	30.4	12.0	104.88	58.0	10.5	174.00	7.00	62.12
Average	33.7	11.9	$132.90	51.9	11.5	$194.21	$ 8.67	$52.65

Table 4 lists selected data from ıdies conducted at the Bluecreek ;perimental Farm. Net return reflects fference in wheat prices and varying ›sts of applying ash in addition to the fects of snowmold. Wheat prices were ghest in 1975 and 1976, which creased net returns. However, results clearly indicate that severe snowmold damage and a reduction in yield occur when soils are unfrozen under a deep snow cover for 70 days or more. Darkening the snow to accelerate snowmelt reduces snowmold damage and thus increases wheat yields, thereby increasing profits.

Darkening Agent-Nitrogen Solutions

In 1984 commercial applicators felt they could increase area covered per load by applying darkening agents in an urea ammonium nitrate (UAN) solution. By using a nitrogen solution (which has a low freezing point) as the carrier for the

'ABLE 4. Effect of treatment with fly ash on days under snow, yield, protein content, and net return.

Year	Continuous days under snow with no soil frost	Reduction in days under snow due to treatment	Increase in yield due to treatment (bu/a)	Increase in protein content due to treatment (%)	Increase in net return due to treatment ($/a)
1975	42	20	8.2	1.8	48.84
1976	118	28	21.4	1.2	97.62
1977	0	8	2.3	0	1.59
1978	50	20	16.3	-0.8	43.07
1979	88	24	20.0	-3.2	39.36
1980			— Ash not applied —		
1981			— Ash not applied —		
1982	86	16	26.1	0.5	91.58
1983	94	24	20.5	-1.3	51.45
1984	79	17	20.7	-0.6	55.29
1985	82	21	27.6	-1.5	62.12
Average	71	20	18.2	-0.4	52.65

TABLE 5. Comparison of liquid and dry methods of applying a darkening agent (1984).

Method	Days under snow		Yield (bu/a)	Protein (%)	Income ($/a)	Cost ($a*)	Net Return ($/a)
	Total	No soil frost					
Liquid	102	64	53.2	11.5	210.14	14.00	84.00
Ash	102	64	54.0	11.9	213.30	15.34	83.26
Untreated	117	79	31.0	10.8	114.70	—	—

*Includes cost of additional nitrogen.

NOTE: All plots had 50 lb. N/A as anhydrous ammonia. Additional nitrogen (14 lb./a) applied to both liquid and ash treatments in the spring.

TABLE 6. Rate of snowmelt associated with darkening materials in UAN solutions.*

Material	Snow depth (inches)						
	Date: 3/19	3/21	3/26	3/31	4/2	4/5	4/10
Fly ash	20b**	17.5d	13.5c	10d	6cd	0a	0
Ground coal	19b	17.5d	13.5c	10d	5c	0a	0
Graphite 3739	16a	12a	4a	0.5a	0a	0a	0
Graphite 3226	17a	13ab	5a	1d	0a	0a	0
Coke (998 carbon)	23c	18de	14d	12e	7d	0.5a	0
Graphite 3124	17a	14bd	10b	5b	1a	0a	0
Graphite 8600	17a	12.5a	9b	7c	3b	0.5a	0
Coal—25% graphite	19b	15c	9b	7c	5b	1	0
Control	24c	19c	17c	14.5e	12e	5c	0

*Source: Tindall 1986 (see References).

**Treatment means followed by the same letter are not significantly different at the 0.05 confidence level.

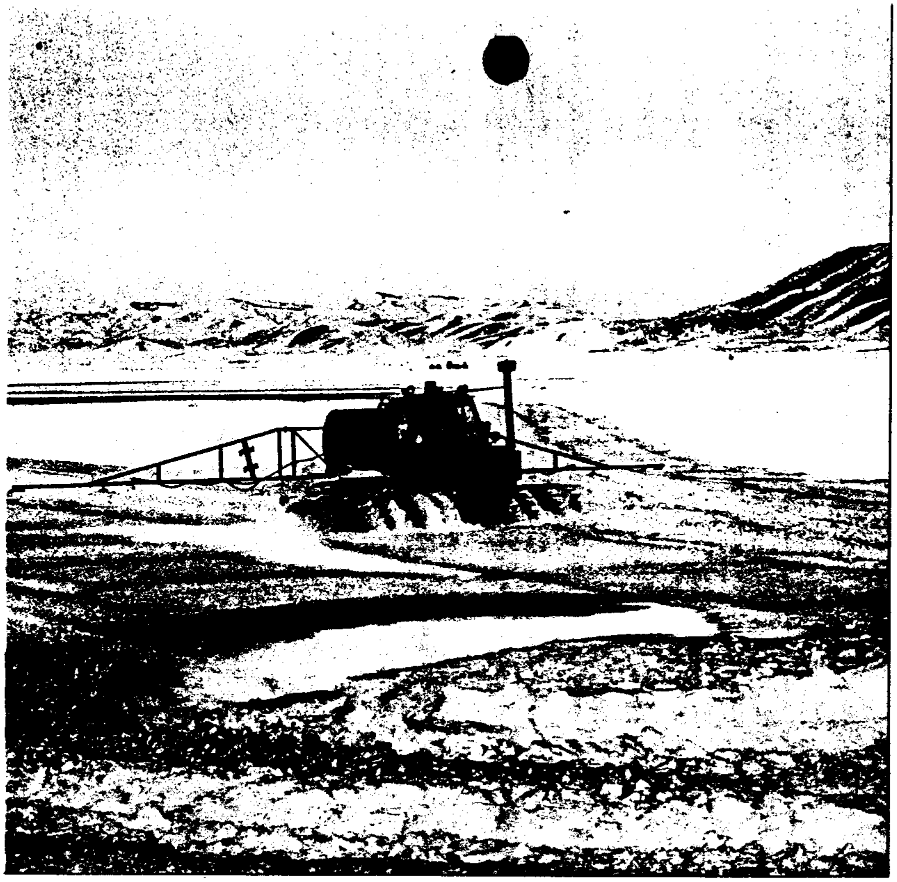
darkening agent such as graphite, additional nitrogen could be applied, thus eliminating a separate trip over the field. In cooperation with a commercial applicator, studies compared the effectiveness of liquid and dry darkening agents. There was no significant difference between liquid or dry darkening agents, but there were significant differences in yield, days under snow, and net returns between treated and untreated areas regardless of the type of darkening agent (Table 5). In the spring, 14 lb. of nitrogen per acre were applied to the plots treated with dry ash; this was equal to that applied to plots treated with a nitrogen solution.

In 1985, Bear River Supply of Garland cooperated in a study of different darkening agents applied at a site in Pocatello Valley (Table 6). Due to equipment malfunction, the maximum ash application rate was only about 100 lbs. per acre. This probably accounts for the slower melt rate on plots treated with ash. Liquid solutions applied by other equipment contained 7 lb. of nitrogen and 18 lb. of darkening agent per acre. Snowmelt was more rapid on areas treated with a graphite-nitrogen solution, and was most rapid on areas treated with graphite 3739. Yields are not shown because nitrogen rates varied; however, yields on all treated areas were significantly greater than on untreated areas.

Conclusions

When conditions favor the development of snowmold, applying darkening agents to increase snowmelt rate is a profitable method of reducing yield losses. Regardless of material used, skies must be clear for 5 to 7 days following application for the material to be effective. Also, the material may need to be reapplied if 4 or more inches of new snow covers the material. If there is less than 4 inches of snow over the darkening agent, it will usually melt, thus revealing the darkened snow.

Dry darkening agents may be any dark material that will spread uniformly and is light enough to remain on the



Applying darkening agent and liquid nitrogen.

;now surface as it melts. Some of the materials that have been used success-ully are furnace ash, dry soil, coal dust ınd dry manure. If a darkening agent is o be mixed with liquid nitrogen, it must ;tay in suspension. Some of the materals used successfully are graphite, coke ınd coal dust. Lampblack is very dark vhen first applied, but flows down hrough the snow with the water, thus educing its effectiveness.

In addition to their benefits in reducng snowmold, darkening agents also ielp control run-off. When darkening ıgents are applied when air temperaures are freezing or below snow melts ;lowly during daylight hours so runoff loes not exceed infiltration into the soil. This reduces the risk of soil erosion later n the spring caused by rapid snowmelt; ı snowpack can melt in 48 hours. How-ver, runoff and erosion could be ncreased if warming temperatures folow the application of darkening agent n mid-March or later.

Recommendations

1. Check wheat once a week and begin monitoring frost depths 2 weeks ıfter deep snow covers wheat. Continue hese weekly surveys until the snow has nelted.

2. Prepare to treat fields at the first sign that frost is leaving the soil. Try to apply darkening agents when weather forecasts indicate skies are to remain clear for 5 to 7 days. Darkening agents may have to be reapplied if new snow covers the darkening agent. However, if enough snow has melted, snow tunnels may collapse around the wheat and retard mold activity. Under these circumstances, reapplication may not be necessary.

3. Don't be overly complacent even if mold is not visible. Apply a darkening agent by late February if deep snow persists and no frost remains in the soil.

4. There appear to be only small differences between the effectiveness of dry or liquid darkening agents. Therefore, the method selected by a farmer should be based on compatibility with other aspects of crop production. It initially costs less to apply ash, about $7 per acre, than to apply a graphite-nitrogen solution, which costs about $12 per acre, depending on how much nitrogen is applied. However, costs associated with dry or liquid materials are about equal if a farmer utilizes a complete program, one involving snow removal, split applications of fertilizer, and herbicide application. Two operations are required in a complete program, whether the darkening agent is a liquid or a dry material. If a dry darkening agent is applied, ash would first be applied to remove snow, and a mixture of liquid nitrogen and herbicide (such as Ally or Glean) would then be applied after the field is bare. A farmer applying liquid material would first apply nitrogen and darkening agent; herbicide would be applied after the field is bare. **It is illegal to apply herbicide on the top of the snow as herbicides are not labeled for this type of application.**

ABOUT THE AUTHORS

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Terry A. Tindall is an extension soil specialist and assistant. He received a PhD at Oklahoma State University. He is currently working on graphite nitrogen solutions applied to snowcover infertility management of winter wheat and rangeland.

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BLUECREEK SNOW REMOVAL STUDIES 1988

Economic Evaluation

	Yield Bu/A	Percent Protein	Gross/A	Cost/A	Net/A
Ash	45.8	13.2	201.98	19.30	45.78
Graphite + 20 + ally	44.3	13.7	195.36	17.30	41.16
Graphite + 20	45.7	13.4	201.65	20.80	43.84
Untreated	33.9	13.8	149.50	12.60	
LSD at .05	6.5	0.9			28.67

Agricultural Research: Your Dollars Working for You

The research results that we chronicle in *Utah Science* represent returns on dollars invested by you. And according to conservative estimates, the rate of the return is an astounding 50 to 1.

The Utah Agricultural Experiment Station's balance sheet shows that about 39.4 percent of its financing comes from state sources, 22.3 percent from the USDA, and 38.3 percent from various federal and industrial grants. The other western stations average 62.9 percent from state sources, 12.5 percent from the USDA, and 24.6 percent from grants. In reality, all the dollars invested in agricultural research come ultimately from consumers – you and I. And it is reassuring to know that our investment is regularly producing tangible benefits.

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But that commitment ca fulfilled only if it is supporte understanding. An understa that must flourish among who have a stake in, and b from, research. So this and issue of *Utah Science* is cated to nourishing the standing of that group consumers – whether t farmers, merchants, makers, doctors, cons workers, or something welcome your commen whether we are on targe

A New Look at Snowmold

Rex F. Nielson and Raymond L. Cartee

Snowmold can be stopped by freezing temperatures or by snow removal.

Snowmold is a disease of winter wheat that has plagued farmers of Northern Utah, Southern Idaho and the Northwest for more than fifty years. Crop losses have involved millions of dollars in reduced yields and reseeding costs. The damage is caused by molds of the *Typhula* and *Fusarium* genera. These organisms are widespread, but they can effectively attack the wheat only when winter snow cover is continuous and persists late in the spring. They are especially dangerous when the soil is not frozen.

The damage resulting from snowmold can range from an occasional plant to an entire field, with losses in excess of 50 percent usually requiring that the field be reseeded. In the winter of 1968-1969, the winter wheat crop in Northern Box Elder County was severely damaged by the mold.

In March of 1969, USU launched a research program to help solve the problem. Workers in the state of Washington had shown that snowmold losses could be reduced by using a blackening agent to hasten spring snow melt. Preliminary trials by USU's Wade G. Dewey on an irrigated site in Cache Valley supported the Washington findings. Based on this information, a series of trials was initiated.

Testing Furnace Ash

The first studies involved furnace ash obtained from the coal-fired heating plant at USU. The material was applied by a cropdusting plane at the rate of 200 pounds per acre. The ash *did* accelerate snow melt, and the incidence of snowmold was markedly reduced on treated areas. Untreated sites suffered considerable losses. The aerial treatments were effective whenever the ash could be applied before damage occurred.

When an airplane is used, the ash must be applied when winds are negligible since drift can be significant. Also, to be economically feasible, the aircraft should be able to land near the field to be treated. We generally could use a hard-surface county road. On a number of occasions, however, snow and ice or high snow banks resulting from the road being plowed made landing impossible. The resultant delay in ash applications often allowed snowmold damage to develop before the field could be treated.

During the past three seasons, we've applied ash from a powered fertilizer spreader mounted on a sleigh and pulled by a snowmobile. By using such equipment we've been able to make detailed studies of the effects of variations in time, frequency and rate of ash application.

As part of this work, we measured temperatures under the snow and at various soil depths. In addition, we noted soil conditions under the snow. Eventually we were able to draw the following conclusions.

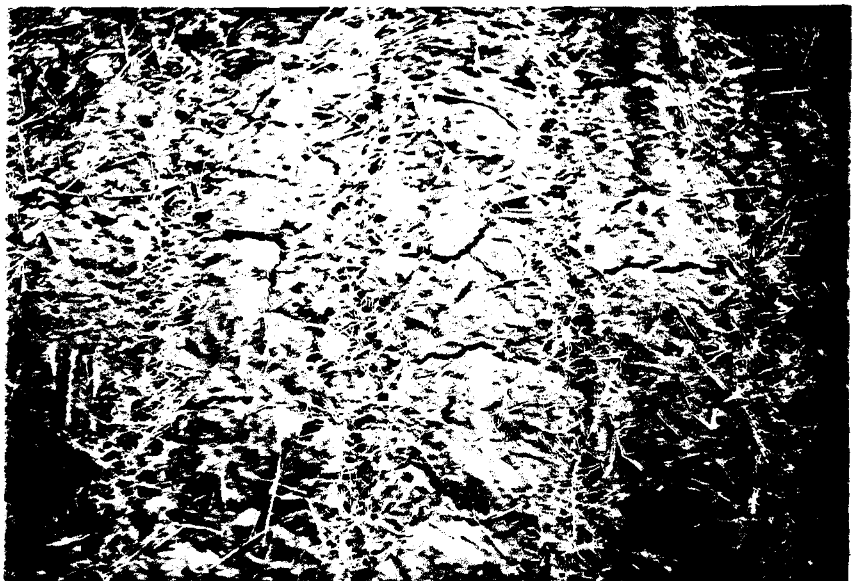

Photo by Rex F. Nielson

Figure 1.This section of the field has *not* been treated for snowmold. All of the plants have virtually been destroyed.

The Hows and Whys

Snowmold rarely develops when a soil remains frozen throughout the winter. But whether or not a soil freezes and how long it stays frozen depends on a number of factors. For example, soil freezes only when water is present. Therefore, dry soils rarely freeze. Loose soils are less likely to freeze than firm soils. Farmers have observed for many years that fields planted with a disk drill suffer less snowmold than those planted with a deep furrowing unit. We now know that this situation is related to the associated looseness or density of soil and its subsequent susceptibility to freezing. Continuously cropped soils suffer more snowmold than those under a crop/fallow program, again with part of the cause related to soil density.

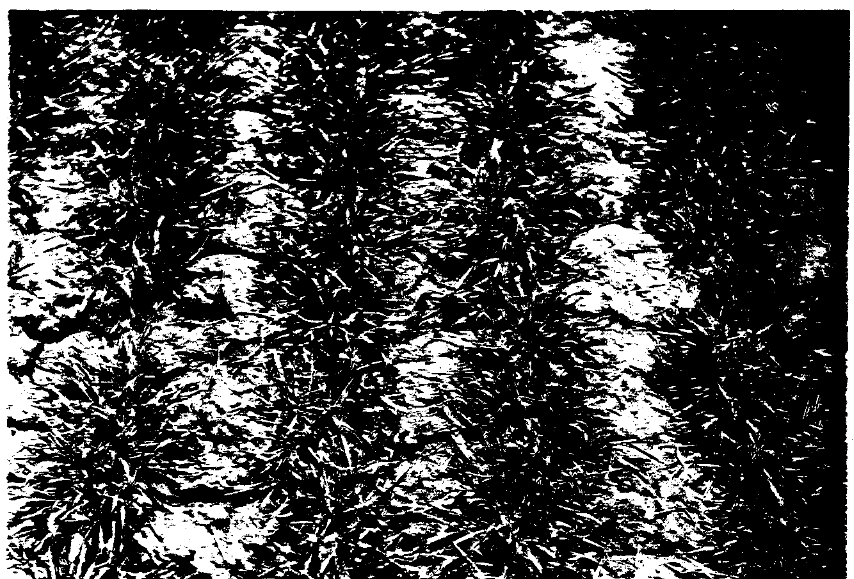

Photo by Rex F. Nielson

Figure 2.Only 30 feet away from the devastated section of the field are these healthy and flourishing plants which have been treated with ash to prevent snowmold.

In Northern Utah, moist soils

without early snow cover usually freeze to a depth of 4 to 6 inches when subjected to low (30° F or under) temperatures. We've rarely seen soils frozen to greater depths.

Once the soil is covered by 6 or more inches of snow, air temperatures have little effect. As the snow depth approaches 18 to 24 inches, the summer heat stored in the soil begins to thaw the soil frost at its deepest level of penetration. This thawing then works its way upward. If deep snow comes in November or early December, it is not unusual for 4 inches of soil frost to be lost to this thawing effect by mid February. We've seen a complete loss of soil frost as early as January 15th. When the soil does not freeze in the fall, either from lack of moisture or an early deep snow cover, it usually remains unfrozen throughout the winter.

Temperatures at the snow/soil interface usually remain about 31 degrees Farenheit over frozen soil. With nonfrozen soil under deep snow, we've measured temperatures of 32-33 degrees Farenheit. This small difference in temperature is sufficient to either inhibit or promote the growth of the snowmold organisms. Once the soil frost is lost, and the snow/soil interface temperature reaches 33°F, the snow begins to melt. With temperatures below the snow above freezing and the moist environment resulting from the melting snow, snowmold can spread rapidly. Where wheat is seeded with a deep furrow drill, tunnels begin to develop above the drill row as a result of the interface heat exchange. Under these conditions, the mold thrives.

Minimizing Snowmold Damage

Snowmold development can be stopped either by freezing temperatures at the snow/soil interface or by removal of the snow. By applying furnace ash, we've controlled snowmold in both ways. The ash sometimes removes the snow and other times reduces snow depths to levels that allow the soil to freeze. The melting induced by the ash changes snow density and thus significantly reduces its insulating capability. In cases of snow removal, subsequent snows have not promoted snowmold growth.

The stage of growth of the wheat plant as it goes into the winter seems to influence its susceptibility to snowmold. Our date-of-planting studies at the Blue Creek Farm in Northern Utah have shown that large, well-tillered plants and very small plants survive and recover from the disease better than do medium-sized plants (see Figure 1). Utah farmers, however, have observed the opposite effect, with medium-sized plants surviving while early and late plantings died. Workers at Washington State University suggest that early plantings result in well-tillered plants capable of surviving the disease. Under Utah conditions, not even well-tillered plants have survived severe infestations. These contradictory data may be attributed to the number of factors that can affect the course of the disease.

At the present time, no com-

Farmers Whose Fields Have a History of Snowmold

To minimize snowmold damage:

1. Begin *weekly* checks of your wheat and the frost status of the soil in early February. These *weekly* surveys should be continued until the snow has melted in the spring.
2. At the first signs of mold, prepare to treat your fields with ash to remove or reduce snow depths. Ideally, try to coordinate with a weather forecast indicating clear skies for five days. A snowfall immediately after the ash is applied will reduce its effectiveness.
3. Don't be overly complacent if you do not see any mold. If deep snows persist by late February and soil frost is gone a preventative ash treatment is recommended.

mercial wheat varieties are resistant to snowmold, although progress is being made in developing strains that are less susceptible and have greater regrowth capability. Meanwhile, the application of furnace ash at the proper time seems the best solution.

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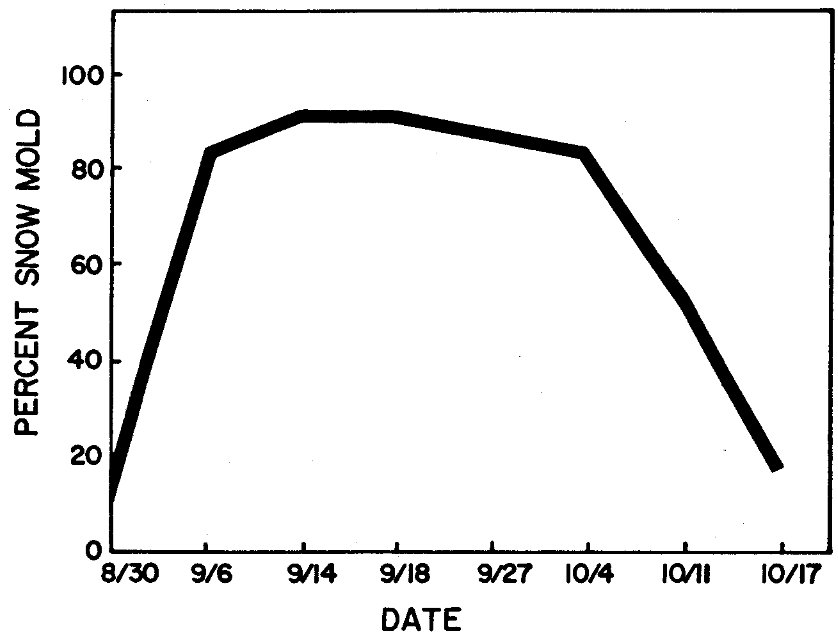
Figure 3. Percent of snowmold as influenced by date of planting, 1974.



Cereal Disease Research

James A. Hoffmann

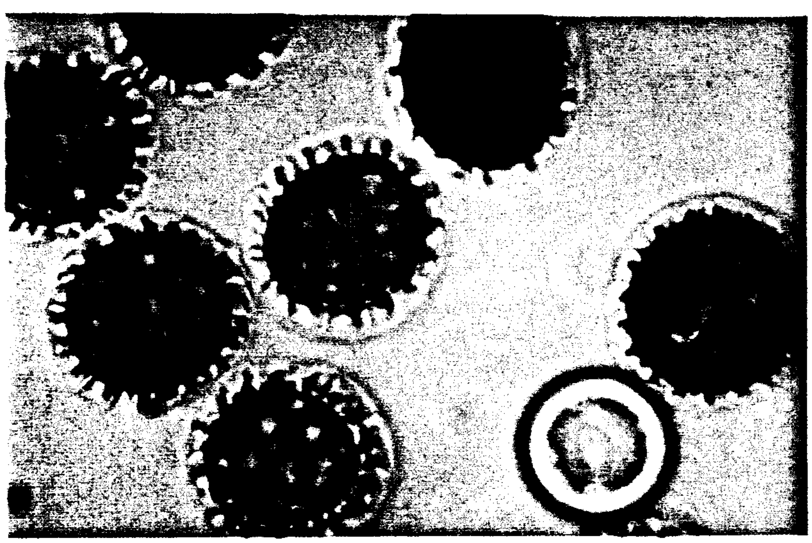
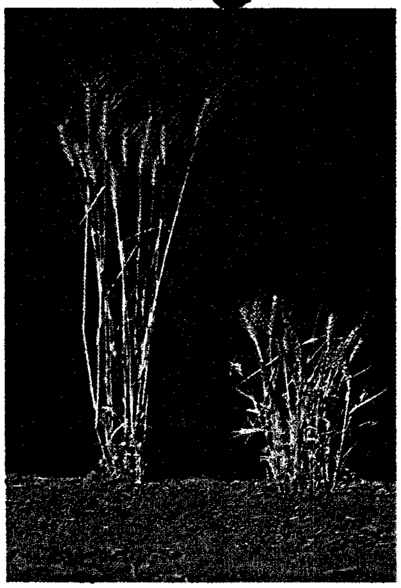


Photo by James A. Hoffmann

Figure 1. Dwarf smut spores as seen under the microscope (magnified approximately 1,500 times).

In the fall of 1972, a portion of the USDA cereal disease program at Pullman, Washington, was transferred to Logan, Utah. The transfer was effected to provide the cereal breeding programs of the Intermountain area with on-the-scene support in pathology. It was also undertaken to give the USDA pathologists a more favorable environment in which to study the dwarf smut disease of winter wheat. Dwarf smut is the major wheat disease problem in the Intermountain area, and in 1973 and 1974 disrupted the area's plans to export wheat to the People's Republic of China. Since the Chinese believe that the dwarf smut fungus is not present in their country, they are understandably opposed to taking a chance on introducing it.



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James A. Hoffmann

Figure 2. A healthy wheat plant on the left and a dwarf smutted plant on the right. Note considerable proliferation of the stalk and a 50 percent reduction in the size of the diseased plant.

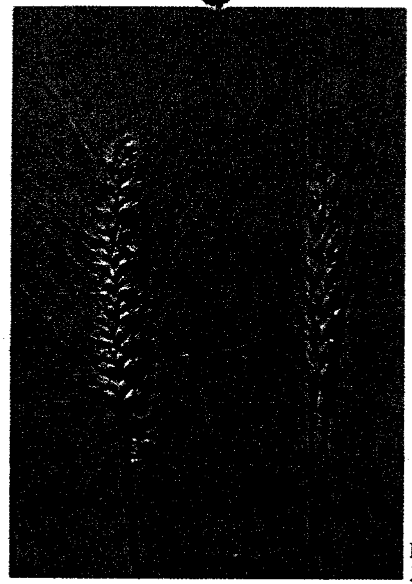

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Figure 3. In these individual spikes of wheat, the awns or beards are extremely ragged in the smutted sample on the left. The black smut balls have replaced the kernels of wheat. The wheat spike on the right is completely healthy.

Photo by James A. Hoffmann

Figure 4. This smutty cloud was a common sight in the Intermountain West during the wheat harvest for many years.